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CONTENTS

ECOLOGICAL CONDITIONS IN NATIONAL FORESTS AND IN NATIONAL PARKS. Dr. Charles C. Adams 561

RADIO TALKS ON SCIENCE:

How Scientific Discoveries are made. Professor Ernest Merritt 594

The Age of the Earth. Frank L. Hess 597

Weighing the Earth. Dr. Paul R. Heyl 602

Radium. Dr. S. C. Lind 606

Earthquakes. Sidney Paige 611

Where are the Stars? Dr. C. G. Abbot 616

THE STATE OF SCIENCE IN 1924:

The Water in the Atmosphere. Dr. G. C. Simpson 621

Weather Forecasting. Lieutenant Colonel E. Gold 629

PROSPERITY AND POWER. Professor Sumner B. Ely and Professor Walter F. Rittman 637

THE PHYSICAL BASIS OF DISEASE. The Research Worker 646

THE CONTENT OF SYSTEMATIC BIOLOGY. Professor G. F. Ferris 653

THE PROGRESS OF SCIENCE:

Sugar from Sunflowers; Measuring Achievement by Ability; The Question of Ether Drift; Methanol: Dr. E. E. Slosson 659

CORRESPONDENCE:

The Governor of California and the Regents of the State of California: President W. W. Campbell; Christian Science: Charles E. Heitman 668

INDEX TO VOLUME XX 671

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THE SCIENTIFIC MONTHLY

JUNE, 1925

ECOLOGICAL CONDITIONS IN NATIONAL FORESTS AND IN NATIONAL PARKS

By Dr. CHARLES C. ADAMS

ROOSEVELT WILD LIFE FOREST EXPERIMENT STATION, THE NEW YORK STATE COLLEGE OF FORESTRY, SYRACUSE, NEW YORK

INTRODUCTION

TWENTY years ago when our party was making ecological surveys of Isle Royal, Lake Superior, I became deeply impressed with the importance of the study of natural conditions. At that time there were relatively few who called themselves ecologists, students of the relation of organisms to their environment, and some of the most competent of these were primarily interested in the application of ecology to economic problems and were to a corresponding degree slightly interested in natural or wild conditions, largely because ecology seemed to them too remote or unimportant as far as their immediate needs were concerned. At that time they had not yet come to realize that one of the basal limiting factors which prevented the better application of ecology to their special subjects was on account of the relative neglect of this science, upon which their progress depended. The applications of ecology to industries and to public policies can naturally progress no faster than the basal science upon which they depend. This is as true of the applications of ecology to our national parks and national forests as of other economic and social problems. The arts of agriculture, forestry, fisheries, medicine and public health are all dependent, to a very important degree, upon advances in our knowledge of the relation of plants and animals to man and also man's relation to his own species.

To-day not only has the number of workers increased, but in addition there has been a greatly improved appreciation of the

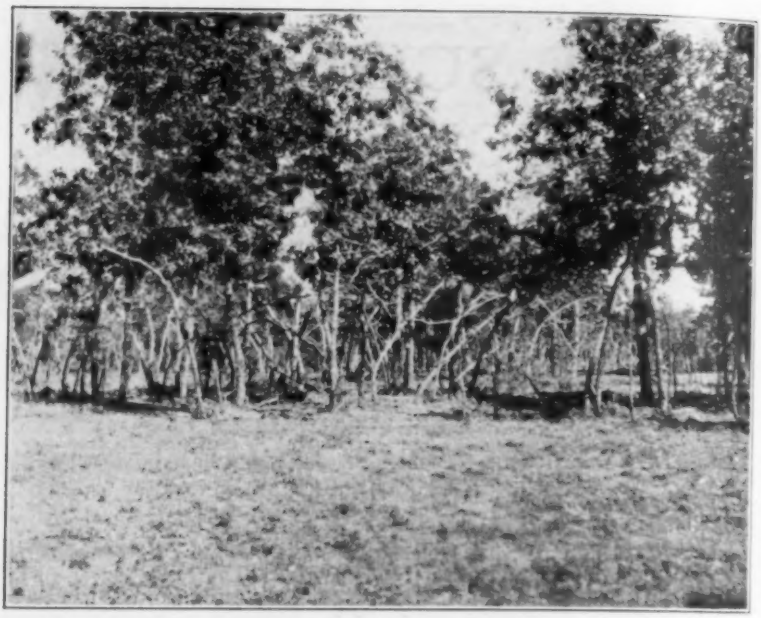


FIG. 1. Overgrazed and overbrowsed Gambel oak, browsed up about six feet, one fourth mile east of old Grand View Hotel, Grand Canyon National Park, south rim of Canyon, Arizona. About one half mile from water.

value of studying wild, unmodified nature, not only for the value of its scientific results, but as well because of the assistance which such studies give in solving practical problems. In recent years there has been a growing recognition of the practical value of wild areas among foresters. The older champions of our national parks, as John Muir, were among the leaders in this country to see in a broad way the value of preserving wild areas, but in recent years there has been an intensive movement to get vast crowds of people into the national parks, and at such a rate that vast areas of the parks are without question being severely injured. The encroachments of agriculture and forestry upon wild lands are also rapidly transforming them from wild areas. Agriculture seems to have practically overlooked the value of preserving wild areas for any contribution which their study can make to this art, although of course for recreational purposes the farmers have eagerly availed themselves of wild areas.

In recent years ecologists and foresters have come to a much better mutual understanding, better in many respects, it seems to me, than between themselves and the students of agriculture. The relation of ecology to forestry has, in the past, been mainly on the

FIG. 2. Overgrazed and overbrowsed cliff rose (*Cowania*), injured and killed, about one half mile east of old Grand View Hotel, Grand Canyon National Park, south rim of Canyon. Scattered lupine in foreground, pinyon and yellow pine in background.

plant or forest side, but more recently the animal aspect of the subject has come in for a clearer recognition, particularly with regard to the influence of grazing animals, and with regard to wild life, and last but not least to the educational and recreational aspect of the subject. The mutual relation existing between ecology as a science and its applications has thus been increased, is much better understood, and we are now coming to see that if we are to preserve in any adequate manner the national parks for future generations there must be applied to them a knowledge of ecology. The relation also of ecology to the forests is progressively receiving greater recognition.

With regard to national forests, as contrasted with national parks, the great bulk of their area is intended to be modified from a wild state to increase their value to man, primarily from the economic standpoint. Here the cutting of timber, the grazing of the forage and the utilization of wild life and the conservation of water and soil are the avowed purpose of these forests. Wild land within such forests, excepting protective forests, will thus be the exception rather than the rule. The vast areas of the forests,

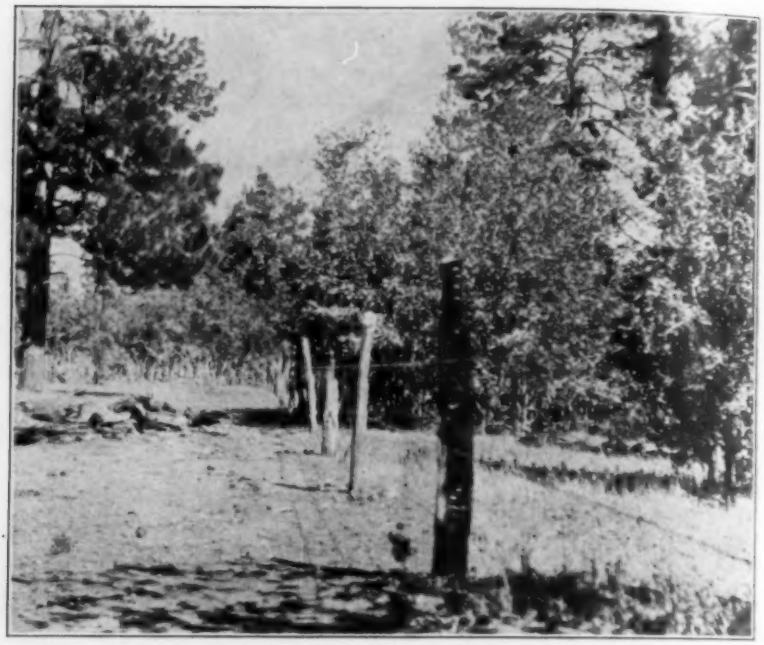


FIG. 3. Overgrazed and overbrowsed Gambel oak, area unprotected by pasture fence, and relatively protected area within pasture, near old Grand View Hotel, Grand Canyon National Park, south rim of Canyon.

with their extensive methods of management or cultivation, give a vast area for ecological study, the ecology of managed forests will be a perennial field for ecological study, and it will furnish one of the most attractive professions for the ecologist.

During the past summer and early fall I made a tour through a number of national forests and national parks. The localities examined were mainly in New Mexico, Arizona, California and Utah, during which special attention was given to the ecological conditions, and to noting the relation which forest and park policies have had upon these. I have tried to look at conditions impartially, and some of the findings I will now discuss. As I have been teaching and investigating animal ecology and its applications to both forests and parks for several years my views have been influenced by certain general considerations, as I view these as phases of the general land problem. I went over the areas rather carefully, took careful notes and photographs, and was generally accompanied by some one familiar with the region and well informed in general on local conditions. I will confine my remarks largely to regions examined during the past season (1924), although

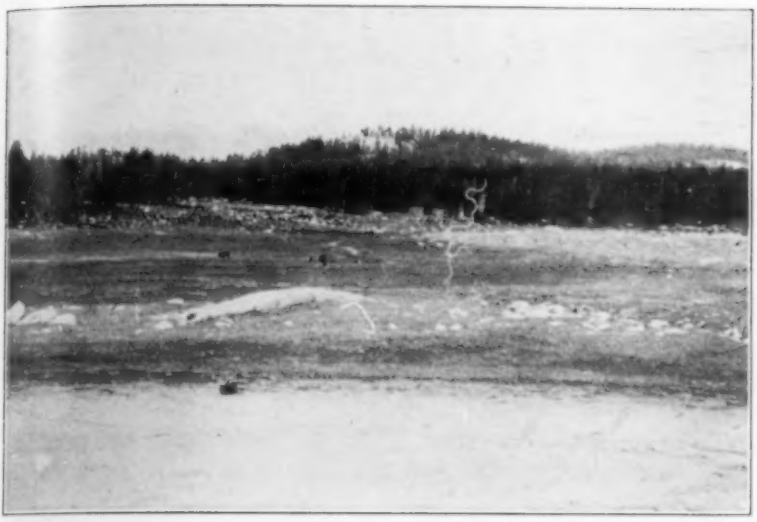


FIG. 4. Overgrazed meadow, with cattle, Sand Meadow, South Fork of the Kaweah River, Sequoia National Park, California.

my observations have not been limited to the regions mentioned. I alone am responsible for the opinions here expressed.

The American idea of a national park is to set aside a region of supreme scenic features as a true sanctuary or haven where plants and animals should be preserved in as near primeval conditions as is humanly possible in this modern world. Such an ideal is a high one and will cost much effort to maintain. It will perhaps require almost as much effort to protect the parks from their superficial unthinking and ignorant friends as from their commercializing enemies and the cheap politicians, who are looking out for their own personal advantage. The national park idea is one of the few valuable American contributions to a policy of land use. It should be conceived in a broad comprehensive manner. At times there has been undue emphasis upon the minor and trivial recreational uses, and not enough attention has been given to the use of the word in its better sense, or "higher use," because without question the educational and scientific and esthetic value of these parks is of supreme importance. As I see it, our national parks are devoted primarily to social uses, recreation, education and science. On the other hand, the national forests have, in the past, been devoted to economic utilization, from the standpoint of timber production, grazing, watershed protection and water power. In recent years, however, the public has invaded the national forests for recreation, and has thus become interested in the forests as never before,

FIG. 5. Overgrazed meadow, Mitchell Meadow, South Fork of the Kaweah River, Sequoia National Park. Near the location of area shown in Fig. 4.

both state and federal, and has forced the national forests rather reluctantly to recognize their interest as one of the major uses of forest land. The tradition and ideal of foresters has been so strongly economic that this social demand has been recognized mainly on account of strong public pressure, rather than by the use of foresight which is generally used in making forest working plans. Certain individuals have, however, grasped this conception very fully. One of the next important practical problems is how to balance properly the economic and the social influences. This the public will decide for itself and we hope under capable leadership. Without question there will be in time a tendency to break down the distinction between parks and forests, but without question the rank and file of the two groups are still so far apart, and it is perhaps well that they are for the present, as both groups have something of importance to learn from each other, before they can work together to the best advantage for public benefit.

I will discuss, first, national park conditions and follow this by considering the ecological conditions in the national forests.

ECOLOGICAL CONDITIONS IN NATIONAL PARKS

Preliminary remarks: During the 50 years in which we have had national parks there has been a growing appreciation of the

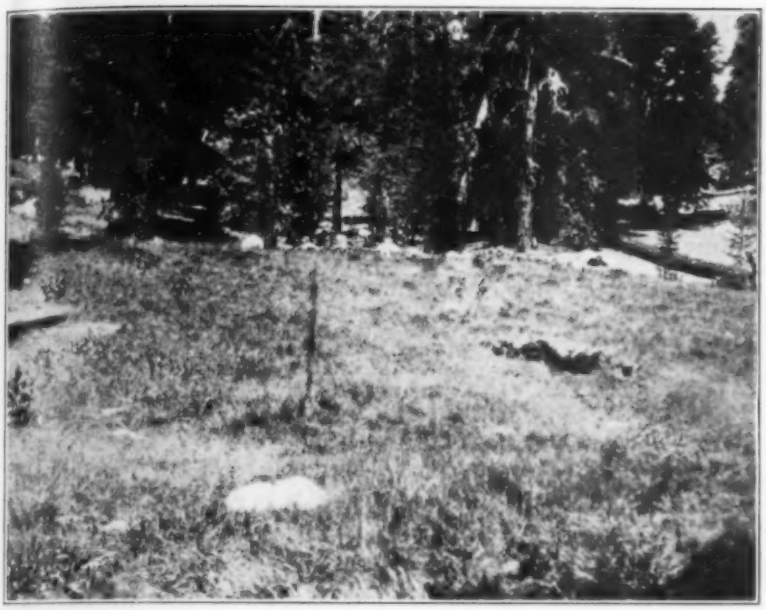


FIG. 6. Protected meadow, showing thriving herbaceous vegetation, near head of Dead Man's Creek, Sequoia National Park.

American idea of preserving for our own and for future generations some of the outstanding wonders, scenic, plant and animal, which our country possesses in unusual abundance. It is remarkable that during all this time there has been no adequate recognition of the fact that these wild parks call for a new profession, far removed indeed from that of the training needed for the formal city park or that of the conventional training of the forester, with a basal knowledge of plant and animal ecology which should be combined with certain arts and methods of administration and an adequate economic and social background. On the other hand, in a much shorter period, forestry has become a profession. The first national forests were created about the Yellowstone National Park, in order to protect it, and now the forests have vastly outgrown the parks in acreage, in organization and in administration.

First of all, we should recognize that the National Parks Service, as a unified organization, was only established in 1916, although the Forest Service was similarly organized in 1905. The founding of the Yale Forest School (1900) was a major influence in professionalizing men for the Forest Service. Several other teaching organizations have since developed so that the forests are now securing the benefit of mature and experienced men, whether or

not they were trained in the schools or worked up through the ranks. There has, however, been no corresponding development of an adequate training for the national parks. The Forest Service has always been in charge of a forester, but the parks have never been headed by a similar technical man.

To interpret fairly the conditions in the parks one must bear in mind this contrast between the administration of parks and the forests. The parks are, in administration, only newly organized and are not yet free of all trace of their former military tradition. They are relatively poor because, excepting automobile licenses, they have no large revenue comparable to the grazing and timber sales of the national forests, and Congress has not yet learned, or the general public for that matter, that in order to administer properly these wonderlands calls for a staff of men—well-trained technical men. The park officials are not yet completely under civil service, and are without a professional tradition behind them, although it should be recognized that this is not always an advantage. We lack therefore in the parks mature and formulated knowledge and policies of park administration.

The Forest Service was for many years overloaded with administrative duties, to such a degree that research was sadly neglected, and during that interval certain errors were made, which might have been less serious if there had been research to guide. The Park Service is now in the same relative position, and even as important as is the position of the park naturalist and the nature guide service, these men are not definitely devoted to technical research, but in the main to elementary educational work with the park visitors. Not all the parks have naturalists, and a considerable amount of their energies is given to publicity. Publicity is of course valuable, but such duties may not allow sufficient time for serious scientific studies. Furthermore, under the present system there has not yet been time to make adequate physical and natural history surveys of their domain, detailed and photographic records of the status and condition of their areas. A considerable body of data of this character must be accumulated, digested and formulated, before each particular park can have satisfactory working plans or policies, such as modern administrative methods require, and such as are found in most of the national forests. If we are to understand the ecological conditions in the parks we must bear these considerations in mind.

These administrative policies of the parks form a large part of the human influence upon them, and are to-day dominating influences affecting the ecological conditions within the parks. Let

us turn to certain conditions worthy of special attention in the Grand Canyon, the Sequoia and in the Yosemite National Parks.

Conditions in the Grand Canyon National Park: The Grand Canyon National Park in Arizona was formerly included within a national forest; it was later made a national monument and finally in 1919 it was made a national park. It is thus a new park and has not yet had time, and with several different superintendents, to settle down to a stable policy based upon a detailed knowledge of the situation. (In passing we should note that the oldest park of all, the Yellowstone, has not yet developed and published its system of management.) The ecological conditions were already greatly modified from a natural wild park when it became a national park. It was considered necessary, in order to get the park established, to permit grazing by local residents who owned some private land within the park. These same persons grazed in the adjacent Tusayan National Forest. The overgrazed condition of the region of the south rim of the Grand Canyon is thus, particularly near the watering places, in exceedingly bad condition, as Figures 1, 2 and 3 show. This excessive overgrazing has made the south rim country of the canyon as severely overgrazed, primarily by domestic animals, as is the north rim in the Grand Canyon Game Preserve, with its excessive number of deer and domestic animals, combined. This is a deplorable condition, which influences the wild life, changes the character of the vegetation, favors the erosion of the soil and produces conditions directly the opposite of the intention of a national park.

As a rule also where grazing animals are allowed there is a more aggressive control of predatory animals, and yet no one has ever made a satisfactory scientific study of this problem in any national park, or for that matter in any national forest, and published the results. As a result of this unsatisfactory condition, and independently of predatory control measures, the rangers in some of the national parks have been permitted, I have been informed on good authority, to trap fur-bearing animals to supplement their meager salaries.

The situation with regard to fishing in the Grand Canyon National Park is representative of conditions in other parks. Thus, the annual report of Superintendent W. H. Peters for the year 1920 states on page 312 that "Bright Angel Creek has been stocked during the year with eastern brook trout."

At the Toronto meeting of the Ecological Society of America, on December 28, 1921, it passed the following resolutions:

Whereas one of the primary duties of the National Park Service is to pass on to future generations, unimpaired, the wilderness of the parks, including their native plants and animals; and

Whereas there are many educational and scientific reasons why the native plants and animals should remain unmixed through importations of other organisms not native to the parks; therefore be it

Resolved, That the introduction of non-native plants and animals in our National Parks be *strictly forbidden* by the park authorities, it being expressly intended that the planting of non-native trees, shrubs, and other plants, as well as the stocking of waters with fish not native to the region, is strongly opposed. Be it also

Resolved, that copies of these resolutions be sent to Hon. Stephen T. Mather, Director of the National Park Service, to Mr. Horace M. Albright, Field Assistant to the Director, and to Mr. Robert Sterling Yard, Executive Secretary of the National Parks Association. (*Ecology*, Vol. 3, pp. 170–171, 1922.)

Dr. A. O. Weese, secretary-treasurer of the society, sent a copy of this to Superintendent Horace M. Albright, field assistant to Director S. T. Mather, to which he replied under date of January 23, 1922, as follows:

My dear Mr. Weese:

I have received copy of the Resolutions of the Ecological Society of America on the native flora and fauna of the National Parks adopted at the recent meeting of the Society in Toronto. I want to say that the present policy of the National Park Service is directly in harmony with this resolution. In Yellowstone Park we do not permit the importation of exotic plants or animals, and we are adverse to the planting of any species of fish not native to the Yellowstone region. In the past exotic fish have been planted in the Yellowstone to the detriment of its waters as fishing streams, but this practice was discontinued some years ago. We are strongly in favor of planting nothing but native or cutthroat trout in most of the waters of the park and confining our plantings of grayling and rainbow and eastern brook trout to streams that have already had these species in them.

I am glad to say also that in my capacity as Field Assistant to the Director I have noticed in my travels among the other national parks that everywhere the superintendents are carefully adhering to the policy of the Park Service that foreign plant and animal life are not to be brought in.

It is a pleasure to know that the Ecological Society is taking such a keen interest in our national parks.

Cordially yours,

HORACE M. ALBRIGHT,
Superintendent.

From the above it is seen that the continued stocking of waters, by exotic species of fish, after they had once been planted, is regularly practiced in the Yellowstone, and by consulting the last annual report of the director it will be seen that this is also done in many other parks. These exotic species, planted by error, should

not be maintained in the parks at all, but should be reduced in every way possible, and no replanting of these species should be permitted. The planting of exotic fish in the Grand Canyon is mentioned merely as an example of a general policy which applies, as has been said, to many of the national parks.

The park officials are certainly to be commended in their efforts to destroy the wild burros which live in the Grand Canyon. They have no value to the park and utilize forage needed for the native wild life.

There is no park naturalist in this park, so that there is no competent man on the staff to study these problems and accumulate data, inform the authorities and to keep the public informed as to the natural history conditions in this park.

Conditions in the proposed Roosevelt-Sequoia region: The Sequoia National Park in Southern California is a high mountain region of great beauty, and is the region in which the giant trees probably reach their ecological optimum. It is, therefore, the region in which the preservation of these forests can probably be made the most successful, and this feature should be made a paramount feature in this park. These trees and their ecological associates form a unique resource which is certainly of national park quality, and nothing should be done which will obscure this feature. The administration of the park should never lose sight of this. In fact, the care and appreciation shown these trees is an excellent criterion by means of which the efficiency of the park service may be judged.

The summer administrative headquarters are located in the Giant Forest, in the finest and largest of all the sequoia groves, and as a consequence of this concentration of traffic, much of the herbaceous vegetation and young trees, which escaped the grazing animals, have been trampled down and destroyed. Cattle and horses have also destroyed much of the low vegetation in the nearby meadows. Of what use are regulations against picking flowers when cattle may eat them? The local officials to some degree appreciate this situation, but they must have public support to remedy it. On the other hand, the local officials have strongly advocated "light burning" of the forest floor, as a means of getting rid of the inflammable litter, including the old fallen trees and stumps.[2] Fires have been a permanent feature of the region, and their complete exclusion will probably in time completely change the appearance of the forest, and probably no one yet knows enough, and has the financial backing necessary, to practice light burning suc-

[2] *Cf.* Ann. Rep. Director Nat. Park Service for 1924, p. 110.

FIG. 7. Protected summer range of deer. Eight deer were seen on this slope at the time the photograph was taken. In the area which it is proposed to remove from the Park and put into a Game Preserve, Upper Soda Creek basin, Sequoia National Park.

cessfully in such a manner as to maintain "virgin forest conditions"! To pass on unimpaired to future generations the park forests is indeed no simple undertaking. In the past there has been some reason for confusion on this subject, but now the results of many years of careful study are available,[3] showing clearly that not only do such fires not really reduce the fire hazard but in fact increase it, that fire favors certain kinds of forests and brush, and thus selects and changes the character of the vegetation, and finally that it really costs more to execute such burnings than it does to give adequate fire protection. To burn over every few years the 161,600 acres of the Sequoia Park and the 719,800 acres of the Yosemite at the cost of from .30 to $1.00 per acre for a total of nearly 900,000 acres would be a very expensive operation. Suppose only 500,000 acres were "light burned" at a cost of $250,000. The last annual appropriations for the two parks totaled only $445,000. To secure such an increase for fire protection alone even over a period of years would be a very serious undertaking, particularly in the face of other acute needs. On the other hand, the fire exclu-

[3] Show and Kotok, U. S. Dept. Agr., Bull. No. 1294, 1924.

FIG. 8. Severely overgrazed meadow, Cahoon Meadow, near the Giant Forest, in Sequoia National Park. Compare with Figs. 6 and 7.

sion methods of the Forest Service cost per year about one and a half to three cents per acre. Thus from every standpoint "light burning" should not be practiced in our national parks.

In this connection attention should be called to the clearing up of the débris produced during road construction, which too often disfigures the highways in the national parks. Some of the débris, as the soil and rock, should be disposed of when the roads are being built, the timber should be salvaged and the brush and stumps should be burned. This plan, however, has not in the past been followed out so that to-day there remains considerable cleaning up to be done, and this is a decided improvement, as has been shown by Superintendent Horace M. Albright.[4] But this sort of cleaning up should not be confused with the burning of natural dead and down timber and other forest litter in these parks. Every field naturalist knows that to remove the dead and down timber would at the same time destroy the necessary breeding sites and cover for many animals.[5]

[4] *American Forests and Forest Life*, Vol. 31, pp. 36–37, 1925.

[5] *Cf.* Grinnell and Storer, 1924, "Animal Life in the Yosemite." Berkeley.

FIG. 9. Giant trees below this gap in Dennison Ridge, on the Tule River slope, showing character of the Sequoias which it is proposed to remove from the Sequoia National Park and place in a Game Preserve. Photograph by courtesy of Ernest G. Dudley.

When the Sequoia Park was made in 1890, grazing was soon stopped but was again permitted in 1917 and continues to this day. The overgrazed condition was quite evident in the two southern townships (Figs. 4 and 5), and it was only in the extreme eastern high part, in the vicinity of Wet Meadows, where the grasslands did not show severe overgrazing, as shown in Figs. 6 and 7. Conditions in the northeastern township, from the Giant Forest to the Mt. Silliman region, suffered more possibly than any other overgrazed area I observed within a park or a forest. The condition of the Cahoon Meadows, shown in Figs. 8 and 11, is a good sample of the overgrazed condition of these meadows, but along the trails the tramping of horses and cattle have done immense damage that will probably require 25 years or more for recovery, and we do not know that even then there will be a true recovery to natural conditions.

The summer and winter range of the deer is a problem of considerable importance. Migratory animals, such as deer and elk, have been the source of considerable friction between the Park Service, the Forest Service and with several of the states. It is well, therefore, to plan to avoid this difficulty rather than to en-

FIG. 10. View from the gap in Dennison Ridge, on the Tule River slope, looking out upon the region with the large grove of Giant trees which it is proposed to remove from the Park. Tops of the Sequoias in the foreground. Sequoia National Park.

courage it by adopting new policies which fail to eliminate this factor. The present Sequoia Park includes some excellent summer range for deer. The best which I saw, and where deer were most abundant, was in the extreme southeastern township of the park (T. 18 S. 31 E.) in the vicinity of Wet Meadows, as shown in Figs. 7 and 11. During one day in that township our field party saw 34 deer and passed through magnificent red fir forests.

It is proposed, in the present Barbour bill (H. R. 4095), now before Congress, to cut out of the park about half of this township, a most important part of this summer range, with the large sequoia grove south of Dennison Ridge in the Tule River drainage, and add to this a narrow strip of forest about Mineral King and make a game preserve of this in the Sequoia National Forest. The occasion for extending a game preserve in the heart of a national park is not evident, and the mines are definitely known not to be of importance. This preserve idea if carried out is certainly destined in the future to make friction. The natural overflow of deer from the park into the forest will be available for hunting without the creation of such a preserve. Furthermore, I see no satisfactory reason for taking out of the present park the large sequoia grove

south of Dennison Ridge on the Tule River slope. This area has, in about 600 acres, as estimated by Mr. Ernest G. Dudley and Mr. H. T. Britten, of Exeter, California, "at least 500 trees over ten feet in diameter." This stand Mr. Dudley states is the "finest body for its size (nearest pure stand) of sequoias in existence." This is the opinion of a forester who assisted his uncle, Professor W. R. Dudley, of Stanford University, in making extensive studies of these trees and who later made a detailed study of sequoias for the Forest Service. Mr. Britten, formerly a park ranger, knows the region thoroughly, has patrolled it and assures me of its accessibility from the Garfield Grove. Without question this grove is of national park quality, as indicated by the trees shown in Fig. 9. It is now in a national park where in my opinion it should remain, and it should not be removed in order to create a game preserve. If these trees are taken from the park, they should be protected specifically by law or made a national monument within the national forest. Standing in the gap of Dennison Ridge and looking south, many of these trees screen the view, as shown in Fig. 10. Such considerations as these mentioned show that, both on account of the deer and the sequoias, these areas should be included within the proposed Roosevelt-Sequoia Park. The accompanying maps indicate the proposed boundary changes, Fig. 11, including a proposed approximate southern boundary line as well as an important addition north of the present park, near Mount Silliman, which is needed to consolidate the park, and to provide for overcrowding, which is already doing the parks great injury. These suggested changes are approved by some of the best informed local men.

Neither in the Sequoia Park or in the proposed park is found the native haunt of the beautiful golden trout named for Roosevelt.[6] This Roosevelt trout deserves more than a passing notice. Evermann has said:

> This is the most beautiful of all the trouts; the brilliancy and richness of its coloration is not equaled in any other known species; the delicate golden olive of the head, back and upper part of the side, the clear golden yellow along and below the lateral line, and the marvelously rich cadmium of the under parts fully entitle this species to be known above all others as the golden trout. In form it is no less beautiful; its lines are perfect, the fins large and well proportioned, and the caudal peduncle strong; all fitting it admirably for life in the turbulent waters in which it dwells. It is a small fish, however. . . . The golden trout is native to Volcano Creek alone, and occurs throughout the entire length of that stream. . . . As a game fish the golden trout is one of the best. It will rise to any kind of lure, including the artificial fly, and at any time of day. . . . It is a fish

[6] *Cf.*, Evermann, U. S. Bur. Fisheries, Vol. 25, pp. 1–51, 1906; Evermann and Bryant, Calif. Fish and Game, Vol. 5, pp. 105–135, 1919.

that does not give up soon but continues the fight. Its unusual breadth of fins and strength of caudal peduncle, together with the turbulent water in which it dwells, enable it to make a fight equaling that offered by many a larger trout. . . . Although now abundant the golden trout can not long remain so unless afforded some protection. The attractiveness of the Kern River region because of its scenic beauty is sure to appeal more and more to tourists every year. Practically the entire length of Volcano Creek is easily accessible from the trail from Kern River to Mount Whitney, and that portion above the tunnel is covered by the trail from the east side of the divide. As a matter of fact one can in one day travel the entire length of the creek and have time to stop frequently to drop a fly into the pools which he passes. The trout are readily found and are easily captured, as they are so voracious and rise to the lure so readily. Two years ago the members of the Sierra Club and others accompanying them on their annual outing to Mount Whitney are said to have taken 600 or 700 trout from Volcano Creek in one day. . . . As already stated, it is only a question of time, a very few years at most, when the golden trout of Volcano Creek will become practically exterminated unless it receives some protection.

Evermann and Bryant in conclusion say:

This, the most beautiful trout in all the world, was named in honor of Theodore Roosevelt, the naturalist, who, as President of the United States, ordered the investigation which resulted in its discovery as a new species.

The preservation of the Roosevelt trout in the Kern River drainage, east of the present Sequoia Park, and southeast of its proposed enlargement (in area No. 2, of Fig. 11) is thus wholly in harmony with the true interests of our national parks and the park boundaries should therefore be changed to include the native haunts of this trout in Golden Trout or Volcano Creek. In the Sequoia National Forest, where they are now located, they are under the control of the state of California. If this proposed park is to bear Roosevelt's name why should the waters including the Roosevelt trout be excluded and why should any of the park and adjacent forest waters containing these and allied fish be stocked with exotic kinds, not native to the park, thus risking the loss of their beautiful native species which live nowhere else in the world? Why destroy the unique features to produce the commonplace? I raise this question of exotic fish because the Loch Leven trout were planted, while I was there this summer, in the waters of the Sequoia Park. This is not in harmony with the ideal of maintaining the unique features of the park unimpaired.

In brief, with regard to the Barbour bill (H. R. 4095) now before Congress, it should be *amended* as follows:

(1) The region including Golden Trout or Volcano Creek, the native haunts of the Roosevelt trout, should be included within the proposed park by adding Region No. 1, of Fig. 11.

(2) The proposed game preserve should be abandoned, leaving undisturbed the summer range of the deer and the big grove of sequoias on the Tule River slope (south of Dennison Ridge) within the park.

(3) The large re-entrant angle north of the present park should be greatly reduced by adding to the proposed park Area No. 2, of Fig. 11.

But this problem of exotic or non-native species is not confined to fish, for I am informed that some years ago an effort was made to stock this park with Chinese pheasants. An effort was made, some years ago also, to stock the park with wild turkeys. Thus Supervisor Walter Fry's annual report of 1916, on page 50, informs us that:

> Wild turkeys are fairly abundant in the Sequoia Park in the vicinity of the junction of the Middle Fork and Marble Fork of the Kaweah Rivers, and there is every indication of their having become firmly established. Of the three different types that were placed in the park during the seasons of 1909–10, *viz.*, Mexican gray, Arizona bronze and Texas black, the two former species seem to have entirely disappeared. This fact is attributed to their either having died, been caught by predatory wild animals, or blended to such extent as to form intergradation to the latter mentioned species. It would seem, however, the latter to be the most feasible of the three causes given. The turkeys range in two separate groups; one that ranges at the mouth of the Marble Fork is quite tame like most other birds of the parks, but the other has a higher altitudinal range several miles in extent and are so wary it is difficult to ever see them.

These experiences with exotics raise a question. Does the public wish to travel hundreds of miles to visit the unique regions of California to be greeted with Chinese pheasants, Loch Leven trout and Arizona, Texas or Mexican wild turkeys, and in all probability at the expense of the native animal species? Clearly this subject is serious enough to deserve more attention than it is receiving. I believe that most of the park officials will readily respond to suggestions from naturalists and the public, but we see how such matters have drifted and are now drifting without adequate supervision.

Conditions in the Yosemite National Park: The Yosemite is one of the best known and most frequented of our national parks. In certain respects this park has had a very progressive history and in other ways its history has been rather discouraging. The Hetch Hetchy Valley episode is a good example of the sinister influences which invade the parks. The state of California deserves great credit for turning over its large area of state land to the federal government for this park. If California would now purchase all the private lands within the park and turn these over to the park, it would be an excellent piece of public work, because without ques-

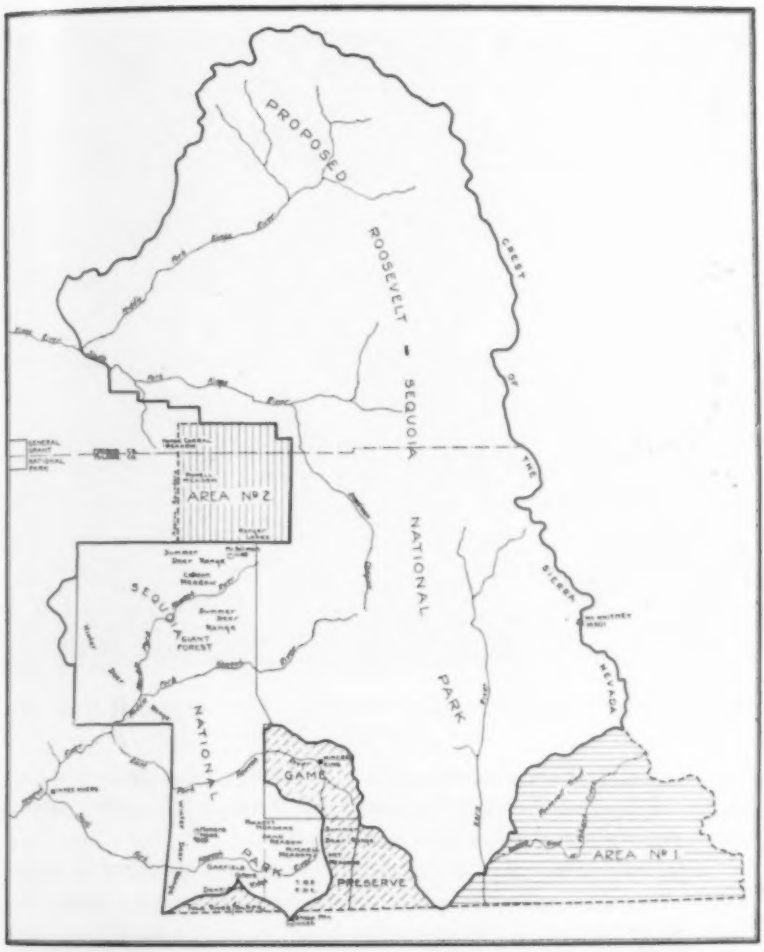


FIG. 11. Map of the proposed Roosevelt-Sequoia National Park region. Showing boundaries of Sequoia National Park, the areas which the present Barbour bill (H. R. 4095) proposes to cut out of the proposed Park, and the boundaries of the proposed Game Preserve. The areas which should be added to the Park are Nos. 1, 2 and the proposed Game Preserve areas.

tion this is one of the greatest menaces to this park to-day. The general public does not seem to be aware of the seriousness of the situation. There are to-day over 10,000 acres of privately owned lands within the park, and over 10,000 have been acquired by the Park Service. But in order to salvage the land along the highway, park timber has been sacrificed. The local officials have had to deal with a very serious problem and have evidently made heroic efforts to make the best of a very bad situation. Lacking funds and authority to prevent the cutting on private lands within the park,

FIG. 12. Mule deer in Yosemite National Park. Photograph used by courtesy of Mr. J. T. Boysen, Yosemite.

their only alternative seemed to be to trade for land along the road, giving more remote and less conspicuous lands, which in themselves surely should never have been cut.

Soóner or later the American public should be fully informed about these private lands within the various national parks, and funds should be provided to condemn and buy all such lands. Furthermore, we are probably drifting toward the position of forbidding the cutting of timber in any of the national parks. Most of these parks are adjacent to national forests and it is from these that all needed timber could be secured. If the forests in these parks should be kept forever wild cutting can not be harmonized with the wilderness condition. Possibly the only solution of these problems is for the Park Service to adopt a policy of intensive improvement of the parks they already have, including the purchase of all private lands within their boundaries, and to delay expansion until the present parks are safe and adequately cared for.

The development of a scientific and educational staff has made unusual progress in the Yosemite. The nature guide service has developed rapidly here, and now with a gift of money from the Laura Spelman Rockefeller Memorial for a museum, there is an

FIG. 13. Mother black bear and three cubs in Yosemite National Park. Photograph used by the courtesy of Mr. A. C. Pillsbury, Yosemite.

unusual opportunity afforded to establish, at least in one national park, an adequate resident scientific and educational staff within a park. The parks are truly in desperate need of such guidance, such as can only be secured from a truly capable technical staff living and working there the year round.

Yet in spite of all this local interest in the welfare of the park, the floor of the Yosemite Valley, as a piece of wild nature, is largely annihilated, and the introduction of exotic Loch Leven trout continues, although the present restrictions on pasturing the meadows will assist in allowing a partial recovery of the wild flowers. Mention should also be made of the introduction of plants by Dr. Harvey M. Hall, of the Carnegie Institution, as a part of his studies in experimental plant ecology. No doubt as long as they are under his supervision they are likely to cause no trouble, but when the experiments are terminated a special effort should be made to see that all the extraneous plants are removed as they should not be allowed to add exotics to the native flora. The eastern opossum, which has invaded Sequoia Park, and is not a native, should be killed off with the excess of predatory animals.

Deer (Fig. 12) abound in the park in summer, but very few indeed remain within it during the winter. At any time this part time seasonal control of the deer may become a serious menace. The presence nearby of the foot and mouth disease in cattle, during the past summer (1924), spread to the deer in adjacent forests, and on the winter range there is an excellent chance to infest the

FIG. 14. Park visitors feeding bears in the Yosemite. A dangerous practice. Photograph used by courtesy of Mr. A. C. Pillsbury.

park deer. This risk alone is a sufficient cause for forbidding all grazing in our national parks. The situation with regard to the bear appears to be more satisfactory. The bears, as elsewhere in the national parks, are very popular with the public (Figs. 13 and 14).

ECOLOGICAL CONDITIONS IN THE NATIONAL FORESTS

Preliminary remarks: As has been indicated the aims and ideals of the national forests are to-day primarily economic, with a rather rapidly increasing recent recognition of the direct social value of wild life and recreation. These differences are reflected in their management policies, particularly in relation to the vegetation and animals of the forests. The trees are considered primarily from the standpoint of timber production, watershed protection or the retardation of erosion, the shrubs largely from the standpoint of shelter, watershed protection and erosion, and as browse for domestic grazing animals and deer, and the herbaceous growth from the standpoint of forage and as a retarding influence on erosion. The larger predatory animals, birds or mammals are looked upon largely as a menace to the grazers or game, to a limited degree as game, and the minor mammals, such as rodents, as competitors for forage or browse. Timber and watershed protection were the older ideals of forestry, but with the inclusion of the open forests and grazing land, wild life and recreation have been reluctantly added,

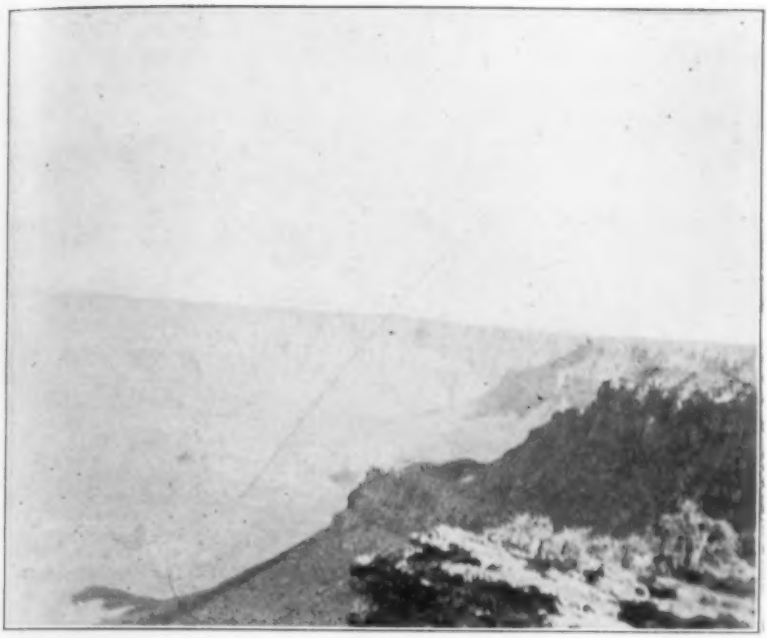


FIG. 15. A side canyon of the Grand Canyon, the western rim of Kanab Creek Canyon, which forms a natural barrier to the extension of the Kaibab mule deer on their winter feeding grounds. Kaibab National Forest, Arizona.

as the regional policy of land use, rather than a tree crop policy solely, has been gaining recognition. There are also healthy signs of recovery from the effort to utilize exotic trees and game, but none yet for exotic fish. The injury and confusion caused by this method of mixing the native and exotic plants and animals have gone on without much regard to the well-known ill effects caused by such mixtures. The results of the introduction of rabbits into Australia, the mongoose into the West Indies, the English sparrow, carp and gypsy moth into America, ought to serve as a warning, with the mere mention of the blister rust of white pine and the chestnut blight. In spite of the fact that we have wonderful native species suited to many purposes there are many persons who are continually, in the face of considerations just mentioned, neglecting the native species and seeking to encourage exotic ones.

It is evident from these considerations that the whole policy of the forests has been in the past to modify the ecological conditions as much as is possible to conform to the extensive use of certain biological resources of the regions, from the standpoint of timber, forage and, more recently, wild life and recreation. To this degree

FIG. 16. The sage brush desert, between Fredonia, Arizona, and the northwestern corner of the Kaibab National Forest and the Grand Canyon Game Preserve. The Kaibab plateau in the background. This desert is heavily grazed by sheep during the winter and is largely Public Domain.

there has been a marked contrast between the theoretical park policy of the wilderness, to which in practice as we have seen, the parks have not adhered, and that of the forests. The policies of the forests are worked out in considerable detail and are based on surveys of almost all degrees of intensity with regard to the timber, to a less degree the forage, and still less so to wild life. Recreational camping has been worked out in great detail in certain areas of the west by the men on the ground who have to deal with these matters, but the results of their studies have not been made public in any adequate fashion.

The Forest Service has always been active in methods of fire control and this has, of course, a powerful influence upon both plants and animals. They have not, however, secured complete control over lumbering methods and brush disposal and until this is done an important preventable cause of fires is not under control. Of course private lands adjacent and within the forests are often a severe fire menace.

The widespread overgrazing seen in the national forests influences the general ecological conditions as a dominating influence.

Not only are the herbs, shrubs and trees influenced directly but as well animals dependent on them. Another condition is greatly modifying natural conditions and that is the practice of the service in its extensive cooperative fish cultural work with the U. S. Bureau of Fisheries and with the states to stock public waters with fish not native to the region.

We see that the ecological conditions in forests are thus undergoing profound changes from wild and primeval conditions and there are almost no parts remaining of these areas which will remain wild, unless a new and definite policy[7] is developed of holding as reserves certain areas. There are, however, many reasons for maintaining such areas for scientific study, demonstration and education and for recreational uses, although this idea has not yet received much recognition in forestry.

The interests of ecologists are not by any means confined to wild areas, or their subjects would be on the decline rather than on the increase. We must recognize, however, conditions as they exist.

Conditions in the Tusayan National Forest: In an arid region the injury caused by fire is very pronounced because aridity makes fire-fighting very difficult, and because the relatively slow rate of plant growth leads to slow recovery. The arid yellow pine and pinyon-juniper forests are so open that they produce forage and browse, and grazing is carried on in them extensively. The limited number and amount of watering places tends to concentrate grazing about such localities, and this results in extensive overgrazing. The use of both the forage, browse and water for stock to a corresponding degree restricts its use for wild life. Thus the control of water at the same time controls much of the adjacent land available for wild life range.

In the Tusayan Forest, on the south side of the Grand Canyon, the dominating ecological condition, now of greatest importance, is the extreme overgrazing, similar to that on the adjacent national park. The condition of the range in the forest and the park are equally bad, so that you can not tell by the appearance of the range whether you are in the park or in the forest. This overgrazing is changing not only the herbaceous vegetation but as well the growth of young trees and brush of all kinds. The brush, such as Gambel oak and cliff rose (*Cowania*), is ridden down by stock and eaten and broken so severely that many of them die. This overgrazing not only injures the normal carrying capacity of the range, but also the reproduction of the trees, and the normal carrying capacity for deer and antelope. It is therefore to be condemned on every score.

[7] *Cf.* Ashe, *Jour. Forestry*, Vol. 20, pp. 276–283, 1922; Pearson, *Ecology*, Vol. 3, pp. 284–287; Leopold, *Jour. Forestry*, Vol. 19, pp. 718–721, 1921.

Predatory and rodent control are carried on by the Biological Survey in cooperation with the state of Arizona. Both of these influences are of course closely related to the range problem. The intensive over-grazing makes the competition with rodents relatively more pronounced and conspicuous and emphasizes the need of comprehensive policies which will balance all these influences.

Conditions in the Kaibab National Forest: On account of the remoteness and inaccessibility of the Kaibab Forest and the Grand Canyon Game Preserve one might expect to find it one of the finest wildernesses and untouched areas in the United States. Bounded as this region is ecologically by the park and Grand Canyon on the south and on the adjacent parts on the east and west (Fig. 15) by side canyons, and around its northerly edge by wonderful extensive deserts (Fig. 16), its position is quite unique on account of this physical isolation. The forests and meadows (Fig. 17) are wonderfully beautiful, and the surrounding country is equally interesting. This would have made an ideal place for a true wilderness preserve. Not ideal, to be sure, for everything that every one might wish to have in a preserve, but certainly an ideal example of a wild area, and one in which there might be some hope of preserving a number of large predatory animals, such as the cougar, as well as deer, as Emerson Hough had hoped. But this forest having been set aside originally as a game preserve where grazing was wanted at the same time, predatory animals have been systematically killed and the stock and deer have been preserved. There was of course provision for utilizing the natural increase of the stock, but the federal game preserve contained no adequate specific provision for taking care of the normal increase of the deer (Fig. 18). The boundaries of the forest and park were changed, but the game preserve has not been enlarged. Naturally a period of stress was not far ahead. The overgrazing, particularly upon the winter range by an overpopulation of deer and by stock (Figs. 19 and 20), has continued, and only within the last couple of years has a serious effort been made to remedy the situation. The overcrowded condition on the summer range (Fig. 7), has been retarded in part by reducing the number of domestic animals. The preserve was formed by Congress in 1906, six years before Arizona became a state and therefore some basis exists for the claim that the state has never had authority over the deer. The Forest Service, which has had charge of the preserve, has been reluctant to grasp this bramble and crush its thorns so that a new situation arose about the deer which renewed the conflict between the Park Service and the Forest Service over this migratory game. For a number of

years I have been convinced that the wild life of the national forests should be under the full control of the Forest Service, as is the case of wild life in many of the national parks, in order that the Service might possess unified control over the forest, and include game management in its proper place within a comprehensive system of forest management. In the case of the Kaibab deer this was such an opportunity, but the Forest Service did not grasp this opportunity, study the situation fully and publish the results of its findings and its plans for management. This opportunity was allowed to slip by, and Emerson Hough, not being satisfied with the wild life management of either the Forest Service or the Park Service, suggested a new and independent plan, which was doubtless a cause of its failure.

Personally I have no choice as to which federal bureau has charge of this area; my only concern is that it be managed properly. I believe, however, that the best use to which the region could be put would be to maintain it as a wilderness and to keep the "improvements"—hotels, auto roads and their like—out of the region. From the standpoint of "highest use," for the welfare of the whole nation, this region could not, it seems to me, be put to better use. Either the Forest Service or the Park Service could care for this area, but their duties should be clearly prescribed by the law; otherwise there will be pressure from those who wish to exploit it for economic purposes.

Development of Park and Forest Policies

Preliminary remarks: The need of public policies for both the parks and the forests is a subject which should be almost self-evident, and yet we have not practiced this thoroughly, so that any one can without considerable effort learn the status of these policies. The Forest Service has published considerable information on certain aspects of this subject and there are books which deal rather fully with historical and legal aspects of it,[8] but we have no corresponding volumes of the parks, although Cameron's[9] volume is a partial substitute for this. Without question the lack of funds for publication has been an influential factor. It seems, however, that a fuller public statement, including even the provisional policies, of at least the more important forests, would be worth the effort. The larger the organization the more difficult it becomes to keep the individual members informed of the status of conditions, and the publication of these policies would help the service itself, as

[8] Ise, 1920, "The U. S. Forest Policy."
[9] 1922, "The National Park Service."

FIG. 17. Park-like meadow in the Kaibab National Forest, south of V T Park, showing the character of the summer feeding grounds of mule deer. Overgrazed by stock and deer. Arizona.

well as its relation to the public. To state the rules of the game and the conditions under which they operate should be salutary in many respects, and help to build up and maintain public confidence. Of course, there will be some disadvantages in following such a policy, but it hardly seems probable that they would overbalance the benefits.

Development of policies from within: I am considering policies as *formulated procedure* which have resulted from an effort on the part of the officials or organization to adjust their relations to the public. It is a response to the conditions, and involves contributions from the officials, or from within the service, and from the public, that is, from those without. Of course, in practice, it is often difficult to tell the origin of a given stimulus, whether from within or without.

The beginnings of our forestry ideas were, like most of our institutions, adapted from European theory and practice, and by degrees they are becoming adapted to our own conditions and institutions. Thus our silviculture tended to be European, but our grazing methods are distinctly American, and the development of our wild life policies and recreation will surely be along American rather than European lines.

FIG. 18. Kaibab mule deer on the summer range, Kaibab National Forest, showing the absence of young aspens caused mainly by overbrowsing by deer and stock. Photograph by courtesy of Mr. Albert Wilkes, Salt Lake City.

There are certain improvements in both the parks and the forests which can be best made from within, and there are others which are most likely to come from without. It is fortunate indeed that the forest service started with a distinct professional leadership and this was possible because European forestry was highly developed. But the idea of wild or wilderness national parks is a distinctly American idea and did not have a European tradition. The European tradition is about formal park design rather than large wild parks, such as our national parks. For this reason we must develop our own policies for the parks, as is being done for grazing and wild life in the national forests. The recreational aspects of both the parks and the forests is largely a new problem in American life, and must be worked out by both the parks and the Forest Service.

I wish to emphasize that the recreational problem of the parks and forests will surely fall far below its best achievement if it does not strive to serve the "highest use" rather than to cater to the common urban amusement resort standard of recreation. We should thus bear in mind that the parks are not set aside solely for recreation, in the limited sense, but are intended for broad public benefit, including education and science. It seems to me that we are fully justified in expecting a very large contribution from within the Forest Service to the cause of recreation and wild life, primarily because this service has long been accustomed to making basal sur-

FIG. 19. A general view of the western part of the fall and winter range of the Kaibab deer, looking toward Kanab Creek Canyon. Kaibab National Forest, Arizona.

veys of the resources, has formulated its method of recording and reporting data, and has for years been accustomed to formulating policies of management upon a long time basis. *I believe that this is the greatest contribution of forestry to our American institutions.* Any interested person who will spend time in the office examining the data on hand or by talking with the officials who deal with timber, grazing, wild life and recreation and who will examine carefully the wealth of data, maps and plans already made for the utilization of these resources, will be convinced of their ability to make a very important positive contribution to these aspects of forestry. Field studies furthermore in the forest will I believe confirm this opinion. Several of these are developments which have come largely from within and, as developed in the west, in response to the public demand. The legitimate public demand for wild life and recreation, particularly in the east and mid-west, is so much greater than our national parks can ever expect to provide that in order to preserve the parks it will be necessary to develop, on a very large scale, the resources and facilities in the national forests.

As has been said on the other hand, the park service is new. It

FIG. 20. A detailed view of the western part of the winter range of the deer, showing the overbrowsed cliff rose (*Cowania*) in the foreground, and severely browsed junipers in the background, Kaibab National Forest and Grand Canyon Game Preserve, Arizona.

has during previous administrations not developed to an equal degree a tradition of formulated surveys, working plans and policies and is more nearly to-day in the position of wild life, and recreation, in the Forest Service. The Park Service has had to begin nearer the bottom and develop its own policies, handicapped by the lack of a certain amount of professional tradition. The result has been a relatively slower rate of development. The Forest Service has had, however, to pay its price for its professional advantage, as this has tended towards a dominance of economic ideals and sentiments, and consequently it has been rather slow in recognizing the full value of social ideals and sentiments. This explains in part some of its inertia in recognizing grazing, wild life and recreation as a part of their problem of working toward a policy involving the highest use of the land. It has even obscured the recognition that this principle of "highest use" is ultimately and essentially social. Even to-day in its research and publications the Forest Service has not shown adequate recognition of this aspect of its field.

It is difficult to generalize in such matters. But every one who has worked in any kind of organization knows something of the difficulties of improving conditions from within. One would prefer to think that improvements were mainly made from within, and yet only too often an outsider can accomplish in a relatively short time what one from within could not do in five, ten or fifteen years of excellent work. The larger an organization the more difficult it is for the higher officials to keep in touch with the men on the ground who are in direct contact with conditions. In my own field work, made in various parts of the country, I have come to have great respect for the opinions of the men on the ground. Often such men are without technical training and may make serious errors in many ways, but when it comes down to fundamental facts of observation and simple interpretation they deserve very careful consideration. The neglect of this on the part of officials, no matter from what cause, to avail themselves of this sort of information is the source of a vast amount of confusion. These men on the ground deserve more recognition than is generally given them.

Development of policies from without: Having called attention to what may be called the internal factors, let us turn to some of the external influences which affect policies. Of course the supreme dominating external factor is the fact that we have had a new country with a public domain, out of which parks and forests could be carved, and new problems have arisen demanding solution as population increased and as the country developed. It is these pioneer conditions that forced the development of grazing upon the national forests and is now doing the same with wild life and recreation. In the case of the parks the great immediate stimulus was the closure of Europe during and after the war to travel, and the diversion of these people to our western national forests, national parks and into Canada. Without question the automobile is a large factor in this situation, and a general movement of the people toward outdoor recreation that has developed with the industrialization and urbanization of our population. These are dominating economic and social conditions which are to-day making up the complex ecological environment of our plants and animals in our parks and forests.

As has been said, the Park Service and the Forest Service each have an important contribution to make toward this problem. The Park Service may well listen in addition to the demands of the transportation and concessionary companies, to many diverse social, educational and scientific organizations who have a true interest in the welfare and the development of park policies. The Forest

Service has also similar obligations not to give too much attention to the economic demands of local lumbermen, stockmen, power and irrigation interests, and to overlook national social welfare. These matters should be weighed carefully with a long look ahead, remembering that social values are difficult to weigh and that it has not been the habit of foresters or their training in the past to evaluate these considerations. It therefore suggests that careful provision should be made for errors. The old criterion of the "highest use" is of supreme importance, and foresters should recognize the "highest" means ultimately social rather than economic values. Both the forests and the parks need to formulate their ideas and criterions of value so that when occasion arises they can dispassionately estimate relative values, or they will not to a corresponding degree hold firmly public confidence.

We meet with public officials who are fair-minded and who welcome an opportunity to explain and improve their policies. At the same time others look upon any suggestion or criticism as a political attack, possibly because too many of their critics have been politicians, or because they consider all criticisms a personal matter, and act as if they and not the public owned the forests and parks, and this of course only causes confusion and more trouble, and is not the successful method of solving problems.

Summary and Conclusions

I have brought these matters before the Ecological Society because I feel that they are vitally concerned with the ecological welfare of these millions of acres of federal park and forest land. From the standpoint of the naturalist these parks and forests contain a vast number of important and interesting scientific and educational problems. To solve these problems involves no new technique for those ecologists who have been accustomed to study the physical environment, the vegetation and the animals, including man, from a dynamic or process point of view. More attention, however, is needed to integrate these dynamic conceptions intimately with current economic, social and political problems.

There is no group of the public which should have a keener appreciation of the value of these regions and a keener desire to see that they are managed to the best advantage. As citizens they should be as much interested as any others, and as naturalists they have another additional interest. There are, then, special reasons why they should take on additional responsibility and assume a self-appointed guardianship looking toward the best management of these areas, and cooperating with other agencies having similar interests.

RADIO TALKS ON SCIENCE[1]

HOW SCIENTIFIC DISCOVERIES ARE MADE

By Professor ERNEST MERRITT
CORNELL UNIVERSITY

I FEAR that the title of this talk may be somewhat misleading—may even hold out false hopes. It sounds as though I intended to explain all the trade secrets of the scientist, so that every one who has the good fortune to listen in will be prepared to make his own scientific discoveries. If the newest dancing steps can be taught by a correspondence school, why not teach the art of scientific discovery by radio? In fact, to bear out the title "How scientific discoveries are made" I ought really to make one or two discoveries myself, just by way of illustration, while the radio audience "stands by."

Nothing quite so ambitious as this is intended, however. All I shall attempt to do is to point out the way in which some of the great scientific discoveries have been made in the past, with the idea that it will probably be under somewhat similar circumstances that great discoveries are made in the future.

For many years progress in all branches of science has been extremely rapid. We have come to take this as a matter of course. If at least one or two great discoveries were not announced each year we should feel that something was wrong and that the scientific machine ought to be speeded up. Some kinds of scientific work *can* be speeded up—for example, measurements or routine observations, and these may be of great value. But *discoveries* are different. No one can make a discovery to order. From the very nature of the case a discovery involves something that is unexpected, and the greater the discovery the more unexpected it is. If you discover something that you know is there it is no discovery.

There is a great deal of similarity between progress in science and the exploration of an unknown country. If an explorer starts out to discover some particular thing, like an oil well or a big water fall or the highest mountain in the world, he is likely to be disappointed. But if he starts out with the intention of simply going as far as he can into the unknown region and finding out

[1] Broadcast from Station WCAP, Washington, D. C., under the auspices of the National Research Council and the direction of Mr. W. E. Tisdale.

what is there, he is pretty certain sooner or later to find something of interest or value. If it isn't an oil well it may be a gold mine. If it isn't a water-fall it may be an equally beautiful lake.

The great thing is for the explorer to keep his eyes open and his mind alert so as to recognize the worthwhile new thing when he sees it. Open-mindedness and alertness are the great qualifications. Even if he has started out to find some particular thing he must be ready to change his plans if circumstances require it. Columbus started out to find a new route to India—and failed. But he discovered America instead. There are many cases like this in the history of scientific discovery. Take, for example, the discovery of radioactivity by Becquerel, which was the result of a combination of plausible but false reasoning and fortunate accident. Becquerel started out from the fact that X-rays had been found to come from those parts of a Crookes's tube which were being bombarded by the cathode rays and which were in consequence brilliantly fluorescent. The fluorescence of the glass was thought to be tied up in some way with the production of X-rays. Now Becquerel knew that certain uranium compounds could be made to fluoresce in sunlight even more brightly than in a Crookes's tube. So it seemed to him likely that X-rays could be produced simply by exposing these uranium compounds to sunlight. He tried the experiment by wrapping a photographic plate in black paper so as to protect it from light, sprinkling some uranium nitrate on the black paper, and then placing the plate in the sun for several hours. When the plate was developed the parts underneath the uranium compound were found to be blackened. Apparently Becquerel's reasoning was correct, and X-rays, capable of passing through the black paper, had really been produced. To make sure he prepared to repeat the experiment. A fresh plate was wrapped in black paper, uranium nitrate was sprinkled over the outside, and he was about to place the plate in the sun, when a storm came up. So he put the plate with its uranium nitrate in a dark closet and went to work at something else. Paris sometimes has pretty dismal weather, and this time it was several days before the sun appeared again. When the sun finally did appear Becquerel thought it was hardly safe to use the same plate—it might have been spoiled in some way through standing. So he prepared a new one. But just for fun he developed the plate that had been standing in the dark. And to his great surprise he found that it was blackened even more than the one that had been put in the sun! As a matter of fact, we now know that the sunlight and the fluorescence of the uranium nitrate had nothing

to do with it. Becquerel's original reasoning was entirely wrong. His results were due to the fact that rays similar to X-rays, but different, were being given out by the uranium all the time. He followed up the lead which this accident had given him, investigated the properties of these new rays, and suggested to Madame Curie the experiments which led to the discovery of radium and gave to us the best means yet known of combatting cancer. The whole subject of radioactivity started from this accident. But it did so because Becquerel had the mental alertness to take advantage of the accident. Many of us would have thrown the fogged plate away and thought nothing of it. Like Columbus, Becquerel failed in what he started out to do. But, like Columbus, he was more successful in his failure than if he had succeeded.

The discovery of X-rays by Roentgen is another illustration of the important part that accident plays in scientific discovery. Roentgen was repeating some interesting experiments that had been made by another physicist with a special form of Crookes's tube. He was working in a dark room, and on the table near his tube all sorts of things were lying around such as a physicist is apt to have in his laboratory. Possibly if Roentgen had been more neat and had kept everything in the right place he would not have made the discovery. Among the things near the tube was a small piece of a certain compound of platinum, and Roentgen noticed that this gave off a faint light every time he operated the Crookes's tube. It would have been easy to fail to notice this dim light or to dismiss it as of no importance. But Roentgen *did* notice it and recognized that he had to do with something new and important. In consequence the X-ray is now available for the surgeon, the dentist and the physician and has contributed to scientific progress in a dozen different fields.

Roentgen's discovery could not have been made except by accident, for the existence of such things as X-rays was not even suspected. This is true with most really great discoveries. It is the business of the scientific man to keep always in mind the fact that such altogether unexpected things exist in nature. In the words of Hamlet, "There are more things in heaven and earth than are dreamed of in our philosophy."

I sometimes tell my students of the experience we had in the Cornell laboratory immediately after the discovery of X-rays was announced. Like every one else we were much excited by the announcement and anxious to repeat the experiments. Among the apparatus in the laboratory we found an old Crookes's tube. We operated the tube, placed a photographic plate near it and got a

picture of the bones of the hand, which still hangs on the wall of my office. Now that old tube had been in the laboratory for twenty years. I had seen it when I was a freshman. Every year it had been shown to classes and operated—and each time it had given off X-rays. For twenty years our laboratory—and every physics laboratory in the world for that matter—had been in a position to discover X-rays. But we didn't. I wonder how many equally important phenomena are going on around us all the time waiting for a Roentgen or a Becquerel to discover them!

Another illustration of this sort of thing might be given from the field of radio broadcasting. The air is full of radio waves from stations all over the country. With your apparatus you can tune them in or out at will. If my talk verges too much on the highbrow you have only to turn a dial, and symphony or jazz will take its place. But suppose you had no receiving set; suppose you had never heard of broadcasting. The radio waves would be there just the same, all ready to add to your enjoyment of life if you could only learn that they exist and invent a receiving set by which to hear them.

I *might* use this opportunity to point a moral—but I think it is time for my radio audience to turn the dial and tune in on something else.

THE AGE OF THE EARTH

By FRANK L. HESS

Early man probably thought little of the age of the earth on which he lived; like a child he merely accepted it, and if he thought of the matter at all, the world was so enormous compared with his own puny size that it must always have seemed without beginning or end, for he saw no signs of either. In his experience anything made, such as a bow, a house or a wall, was made from something else equally visible, equally tangible and obtained from a known source. But the earth was too over powering. He guessed at its limits because everything else he knew, except time, had its limits. Even the sky came down only to the horizon, but when he traveled across the earth he always saw sea or land beyond. To him there was no end.

New ideas usually arise from a class that has leisure to sit down and think, and the existence of such a class means a fairly high state of civilization. Perhaps the priests of the ancient religions were the first to have this leisure, and they were also among the

ablest men of their nations. It is said that the Chaldean priests left observations of the stars dating back six thousand years and that they claimed to have observations running back four hundred and seventy thousand years, to a date at which they placed the creation of man in a world which, according to their reckoning, had already existed 2,150,000 years. This statement of the world's age was, of course, pure invention, as was that of Zoroaster, who is thought to have lived about one thousand years before Christ and who placed the age of the earth at seven thousand years.

In 1650 Bishop Usher published a chronology of the Bible, in which he paid no attention to the imagery of the East, in the language of which Moses wrote, nor to the indefinite time often indicated by the word "day," so that he counted the six days of creation as six periods of twenty-four hours, with the result that he placed the beginning of the world at 4,004 B. C., probably the shortest estimate yet made. His figures have been utterly disproved, but they are still printed in the margin at the beginning of some Bibles.

Unfortunately, many have treated the estimate of the really learned bishop as an integral part of the Bible, and the development of the science of geology has disturbed them greatly, because they felt that any deductions concerning the earth's history that were not in accordance with his chronology and with a narrow interpretation of Genesis were a direct blow at religion.

But there were many evidences of a vastly greater age than could be compressed into six thousand years. For instance, shells were found in hard rocks and they were so like living organisms that it could hardly be doubted that they too had once been the protecting houses in which snails, oysters, clams and other animals lived and died, though they must have existed a tremendously long time ago. This idea was attacked as irreligious. It was said that these fossil forms were the work of the devil or imitations made by the Creator. However, shells could be traced back by easy steps from those alive in the water to those dead on the beach, buried in the sands, encased in partly hardened sands or muds, and on down through the solid rocks.

Leonardo da Vinci, the artist-scientist, who was a contemporary of Christopher Columbus, recognized that the fossil shells had been living forms. By the middle of the eighteenth century an orderly succession of the shells was determined. To-day fossil shells are constantly used for telling the comparative age of the rocks, though they do not tell us the age in years.

Many other things show us that the earth is old. We watch a tiny stream of water run down a dirt slope. In a few days, or per-

haps even in a few hours, it has cut a considerable trench, but to cut through rocks takes immensely longer. However, we see the same sort of a cut made through the rocks and on a larger scale by a small creek, by a larger creek and by a river, and then we comprehend that even the stupendous canyon of the Colorado, which Dr. George R. Mansfield discussed before the radio audience last summer, was formed in the same manner. Obviously, the time required to cut such a chasm and to carry the waste down to the sea is not to be measured in days or centuries but in millions of years.

How slowly valleys may be cut is shown by the huge redwood trees of the Sierra Nevada in California. These trees grow along the slopes bordering small streams, and some of them show by their rings of annual growth that they are six thousand years old, an age that takes them back to the time when good Bishop Usher thought the earth was "without form and void"; yet the valleys have changed but little in these thousands of years, else the trees must have had the earth washed away from their roots and they would have toppled over and died.

Old as these trees are, they present only a part of the testimony that the redwood family can give us concerning the age of the earth. At Florissant, Colorado, there are stumps of trees eight or ten feet in diameter, long since turned to stone, that also were redwoods, possibly of a type that was ancestral to those of our day. These trees died and were petrified before the great-great-grandfathers of the California trees had sprouted, yet the Florissant trees also must have reached an age of several thousand years. A nearby volcano threw out great quantities of ash that killed and covered the trees, a lake was formed over them, and during the course of the ages the wood of the trees, bit by bit, was changed to flinty stone. Other falls of ash came, covering and preserving many species of leaves and myriads of insects. All this happened in what is known as Miocene time, one of the short periods of the geologist's scale. In the fulness of time the volcano died, the rocks cooled and ice, snow and running water began their devastation. The outlet to the lake was cut down, and the stream cut its way through the lake beds, which had by this time turned to rock, and exposed the stumps, leaves and insects. The crater of the old volcano was washed away and rounded off. Ages passed, man came and discovered gold in the rocks filling the throat of the old volcano, founded his mining camps of Cripple Creek and its satellites and drove his little shafts three thousand feet deep into the rocks.

How long even these shorter periods were may be feebly shown by another illustration: In the oceans and in many of our fresh

waters grow tiny plants known as diatoms. They have marvelously beautiful skeletons of silica, which remain after the softer part of the plants decays. The skeletons are so small that 30,000,000 of them would make only a cubic inch, and even that would be mostly cavities, yet at Lompoc, California, they form beds 1,800 feet thick. The beds were formed during Miocene time, probably while the redwoods were growing at Florissant. Nobody knows just how fast diatoms can grow, nor how fast they can accumulate, but it seems probable that they could not deposit annually more than fifteen or twenty deep, making a layer about one sixteenth inch thick. If they grew at Lompoc at this rate then it took about 350,000 years for the entire deposit to form. But this was by no means all of Miocene time.

These things give us a glimpse of time gone, but not an understanding of it. Down in the Grand Canyon the river has laid bare muddy sandstones of Permian age, which, had they been deposited in the same column, would be thousands of feet below the diatoms of which I have just spoken. In these sandstones are tracks of some huge unknown animal, and the tracks lead directly under the rocks a thousand feet below the top of the canyon—"footprints on the sands of time," inconceivably old, marching into the darkness of the ages, a fitting figure of our efforts to look into the past.

Not until the nineteenth century did scientists really attempt to estimate the age of the earth. Data on which to found an estimate had been too few and too uncertain. By that time, however, great numbers of sections of the sedimentary rocks had been measured, and many observations had been made on the rate at which the streams were moving the surface of the land into the oceans. The problem was attacked by various investigators from various angles, but all were practically agreed on a few important facts that would serve as foundations. In general they agreed that:

At one stage in its earlier history the earth was a molten mass, which slowly cooled.

After it had cooled below the melting point of the rocks a crust formed, and after the crust cooled below the boiling point of water, the water as rain and later on as snow and ice began to attack the rocks, as water is doing today, breaking them down and moving the material, partly in solution, partly as visible particles of clay, sand and gravel, toward the ocean.

The material carried into the ocean in solution largely remains in solution, but the solid particles formed beds or strata of shale, sandstone and conglomerate totaling many miles in thickness. At the same time the remains of animals living in the ocean formed beds of limestone.

Movements in the crust of the earth have caused the strata thus formed to be exposed as dry land, where they may be examined by man.

A number of scientists attempted to solve the problem of the world's age by estimating the time required to deposit the sedi-

ments in the ocean, but the estimates of the thickness of the sediments varied from twenty miles to a possible one hundred miles, and the estimates of the rate of deposition varied as largely. Other scientists attacked the problem by estimating the quantity of salts in the ocean. Many careful analyses of river waters, showing what salts they carried in solution, were at hand, and many analyses of ocean water were made. From these figures and from measurements of the rate of flow, the quantity of salts carried to the sea annually by all the streams and the total salts in the ocean were estimated, and these results were used as a basis to determine the time required to accumulate the oceanic salts.

All these estimates had reference only to the age of the earth since it cooled. As would be expected from the number of unknown factors, the results varied widely and ranged from 3,000,000 to 1,600,000,000 years. The largest figure was obtained by W J McGee, of the United States Geological Survey, and came remarkably close to some of the most recent estimates, though at that time it was considered to be entirely out of reason.

In 1896 the world was startled by the discovery of radium, an element that is constantly breaking down and forming new elements. In the intense research that followed this discovery it was found that radium is a product of the disintegration of uranium, one of the rare metals, and that the final product of a series of changes is lead. It was also found that the element thorium is disintegrating in exactly the same way and that it, too, gives lead as a final product. Of the greatest importance was the discovery that in no way is it possible to vary the rate of disintegration; it is always the same.

During the disintegration of both uranium and thorium, atoms of helium are thrown off. Helium is a very light inert gas, that is, it is a gas that combines with nothing else, so that it is non-explosive, and for this reason it is used in our newest dirigible, the Los Angeles. It is these atoms of helium, thrown off at tremendous velocity, that cause the luminous figures on your watch to glow or makes shining spots that show you after dark where to find the chain pull or the switch for your electric light. When a uranium atom has thrown off eight atoms of helium it becomes lead; likewise a thorium atom becomes lead when it has thrown off six atoms of helium. The number of helium atoms thrown off in a given time by radium was counted, and the rate of production of lead from uranium per year was calculated. For the first time a real measuring rod of known length was put in the hands of scientists with which to calculate the age of the rocks, for the lead formed from uranium or thorium would remain in the minerals unless removed by outside

agencies, and if the quantity of uranium and of lead in a mineral is determined the calculation of its age becomes a comparatively simple matter.

Like the teeth of a horse or the rings of a tree, the lead that the minerals contain tells their age.

Taking these minerals as a guide, the investigators have found that some of the rocks are surprisingly old. A youthful uranium deposit at Lusk, Wyoming, is found to be about 32,000,000 years old. Minerals in the prime of life from Glastonbury and Portland, Connecticut, are about 340,000,000 years old; those from Branchville, in the same state, are slightly older brothers, the difference in their ages being only 90,000,0000 years. Minerals from Ontario, Canada, have reached maturity and are apparently 1,300,000,000 years old.

We don't know how far back toward the beginning of the world these figures go. Possibly half way—maybe more, maybe less. The subject still needs study, and the National Research Council has appointed a Committee on the Determination of Geologic Age through Atomic Disintegration to take up the matter. And at some future time we shall hope to discuss this subject further with you.

WEIGHING THE EARTH

By Dr. PAUL R. HEYL

BUREAU OF STANDARDS

HAVE you ever wondered, when you have seen men excavating the cellar of a building and taking away the earth a ton at a time, how many tons there might be in the whole earth? Scientific men are the greatest wonderers to be found anywhere, and they have not only asked themselves this question (there was no one else to ask) but they have devised experiments to give the answer. It is, of course, a very large figure; about six thousand million million million tons; six followed by twenty-one ciphers. The number is really known a little more accurately than that; the first three figures are known, if any one should need them, and experiments are now in progress at the Bureau of Standards which, if all goes well, will give the fourth figure.

But why should any one need to know this number at all? Of what possible use can it be to anybody?

There are two answers to this question.

In the first place, a knowledge of the mass of the earth is of interest to astronomers, for it is a starting point from which are

obtained the masses of the moon and of the sun and of the other planets of the solar system. Our earth, therefore, is a natural standard of reference with which other quantities are compared; and it is the business of the Bureau of Standards to determine such fundamental reference quantities as accurately as possible.

In the second place, a knowledge of the earth's mass enables us to learn something about the interior of the earth, that region about which so much imaginative literature has been written, and which no one can ever hope to investigate directly. From the earth's mass we can calculate its density, that is, the number of times it is heavier than an equal globe of water; and this leads us to a rather remarkable conclusion.

The various rock materials which make up the outer layer of the earth, which are accessible to test and measure, turn out to have an average density between two and three times that of water, while, curiously enough, the figure for the earth as a whole comes out about twice this value. The inference is obvious: the core of the earth must be composed of something much heavier than the outer crust.

What can it be?

For this question, too, it is possible to find an answer. Several lines of argument, including the speed of travel of earthquake waves, the phenomena of terrestrial magnetism and some others, have led those who have given most attention to the subject to the strange conclusion that the core of the earth is a great ball of iron!

Occasionally there fall to the earth bodies called meteorites, which are often composed of metallic iron, sometimes with a stony admixture. These strange bodies seem to be floating about in space, and occasionally one of them comes near enough to the earth to be drawn in by its attraction. The idea is that the earth is like a great meteorite, or the result of the accretion or massing together of many such particles, in which process the heavier iron portions have gone to the center by virtue of their own weight, or attraction for each other, while the lighter stony portions formed the surface layers. The meteorites that fall to earth may thus be regarded as chips left over or unused portions of material.

So much comes out of an apparently dry and abstruse determination of a numerical constant of nature!

How is the earth weighed? Like many other scientific measurements, this operation is carried out by a roundabout process.

The first thing to do is to set up a miniature system representing the earth and a body near its surface, and determine by experiment the actual force of attraction between these bodies. This force de-

pends on several things: in the first place, on the masses of the bodies, greater bodies attracting each other with more force than smaller ones; and second, on the distance between their centers, bodies attracting more strongly the closer they are together. All these quantities are measured in the miniature system: the masses of the two bodies, their distance from each other and the force of attraction between them.

In the actual case of the earth and a body on its surface, we can measure all but one of the quantities involved. We can weigh the small body and thus determine the force with which the earth attracts it. We can determine by the same operation the mass of the small body, and we know the distance from its center to the center of the earth. What we do not know is the mass of the earth. But by applying the results of our miniature experiment, in which every quantity was known, and solving a problem in proportion, we can calculate the mass of the earth.

The most difficult part of this experiment is to determine the force of attraction between the miniature earth and the small body attracted by it. Even with a mass of steel weighing 140 pounds (which is used in the arrangement employed in the experiment now in progress at the Bureau of Standards) and a ball of gold weighing an ounce and a half the force is measurable only in millionths of a grain, in metric units, about a thousandth of a milligram.

To determine this very small force with the necessary precision an arrangement called a torsion pendulum is used. A light rod of aluminum about eight inches long is hung by a very fine filament of tungsten at its center. This filament is such as is used in incandescent lamps. The rod hangs in a horizontal position and carries at each end a gold ball. The rod swings very slowly back and forth in a small arc, with a time of swing of about half an hour. So delicate is this arrangement that a very small force applied to the balls will perceptibly alter its time of swing.

The swinging system is enclosed in an airtight case from which the air is exhausted. This eliminates trouble from air currents which might disturb the swing and also allows the system to swing for a long time before coming to rest.

Outside this case the two large steel masses are placed, at first as close as possible to the gold balls inside. In this position the time of swing of the torsion pendulum is measured. The steel cylinders are now moved as far away as possible from the balls and the time of swing again measured. Due to the diminished attraction of the steel masses for the gold balls at the greater distance, the time of swing is now found to be about five minutes greater.

From observations such as these the actual force of attraction between the steel cylinders and the gold balls can be calculated.

So delicate is a well-arranged torsion pendulum of this character that the presence of a person within ten feet of it will alter its time of swing because of the attraction of the person's body for the gold balls; or if a car is driven up outside the laboratory and parked the torsion pendulum will indicate its attraction. To avoid disturbances of this nature the apparatus is set up in a room thirty-five feet underground, where all moving masses are overhead, and have no effect on the pendulum.

This is not the first time the earth has been weighed. By the use of apparatus similar to that which has just been described this experiment has been conducted several times in the past century, with results of increasing precision as the technique of laboratory practice has gradually been perfected. No work of this kind has been done for a generation, and it has been thought that sufficient progress has been made in that time to warrant the attempt to obtain another figure of the weight of the earth.

About thirty years ago a piece of work of this kind was performed which has about it so much of human interest that it may be told here profitably.

As has often happened, two men worked on this experiment at the same time without knowing of each other's doings. One of them was a British scientific man, Professor Boys, who worked with the best facilities that London and Oxford University could furnish him. He spent several years at the task and obtained what was believed to be the most accurate figure obtained up to that time.

While he was doing this, another man, of whom Professor Boys had never heard, was working at the same problem hundreds of miles away in Bohemia. This man was Dr. Karl Braun, who had been a Jesuit teacher of physics all his life. At an advanced age he retired from teaching and was sent to a monastery in the mountains of Bohemia to end his days peacefully and quietly. But Dr. Braun could not content himself in inactivity, and for something to do set up an apparatus in his cell in the monastery and determined the weight of the earth. His result, when published, was almost exactly that obtained by Professor Boys.

Much of Dr. Braun's apparatus was made by himself. It is noteworthy that he was the first person to use a vacuum about his torsion pendulum with success. Professor Boys, in his published paper, said that he believed the use of a high vacuum to be impracticable.

Professor Boys could hardly credit Dr. Braun's achievement, and made the long trip to Bohemia to see him. He found Dr.

Braun, at that time over eighty years old, planning a repetition of his work to eliminate some errors which he had recognized. Unfortunately, he did not live to do this.

A few years later, Dr. Burgess, the present director of the Bureau of Standards, carried out an experiment of this nature involving several novel features at the Sorbonne in Paris. He did not, however, succeed in improving upon the figure obtained by Boys and Braun. Since that date no work has been done on the question, until it was taken up again, under the auspices of Dr. Burgess, at the Bureau of Standards.

Nothing, it would seem, is too large or too small for men to attempt to weigh and measure. In this experiment that I have just described to you both extremes are to be found. The enormous mass of the earth is determined by measuring a force so small that only the most delicate pendulum known will detect it.

The enormous distances from the earth to the sun or to the stars do not appal the mind of man; neither do the inconceivably minute quantities involved in the study of the structure of atoms. Anything that exists is a fit object for study, no matter how large, no matter how small. Man may be but the merest speck in the universe, yet in his intelligent comprehension of it he is but little lower than the angels.

It is said that at one time an astronomer discovered a new star, which appeared to be approaching the earth with a great velocity. Night after night he studied it, finally becoming convinced that it was destined to strike the earth. He calculated that this would happen within a few years. Night after night he watched this approaching doom, fascinated by it. He did not announce his discovery, fearing to witness the orgy of lawlessness and despair into which it might plunge the world.

One night he spoke aloud and addressed the star as follows:

> I know that you will soon destroy me and all things living. I can calculate the day, nay, even the hour when this will happen. Yet you are but a blind, brute thing, and I would not change places with you!

RADIUM

By Dr. S. C. LIND

U. S. BUREAU OF MINES

In 1898 a new metal was discovered in Paris by Professor and Madame Curie. Because it was found to give out certain kinds of rays continuously they called it radium. In fact, it was by means

of these rays that the discovery was made. No other chemical element has ever attracted so much popular and scientific attention. Entire institutes have been devoted to its study. Medical clinics have been founded for its therapeutic use. Industrial companies have been formed and plants erected for its commercial production. Millions of dollars have been invested in it, and yet the entire output—all the radium that has been extracted in the world—would weigh less than ten ounces and could be put into a small teacup.

What are the remarkable properties of radium which attract so much attention? Scientifically its discovery represented much more than finding merely another new element. Radium is an entirely new kind of matter. Before its discovery it was thought that the chemical elements, about ninety in number, of which all substances are composed, were immutable. The alchemists spent a century of vain endeavor to transmute the metals. Their failure resulted in the belief that the elements could neither be destroyed nor changed one into another.

The early studies of radium disclosed apparent contradictions to this and other natural laws. Radium was found to evolve heat continuously and to emit rays and high velocity particles which produce electrical charges in surrounding matter. These new phenomena remained unexplained until 1903, when two British scientists, Rutherford and Soddy, proposed the theory of atomic disintegration. This theory has been proved correct. According to it the heaviest elements are in a state of evolution or change into others of lower atomic weight. This change is accompanied by the emission of rays. The two heaviest metals, uranium and thorium, were well known long before the discovery of radium, but it was not even suspected that they were slowly changing to lighter elements. Each of them is the parent of an entire family or series, consisting of a dozen or more members. Radium is merely one of these members, about midway in the uranium family. The moment of change from a parent element to the offspring is all-important, for it is at this time only that rays are given off. In fact, they are the necessary accompaniment or cause of the change. Since very small quantities of matter contain billions of atoms, some of them will always be changing at any instant, and so the change appears continuous and uniform, though it is really made up of a large number of separate events.

The time required for half of any quantity of an element to change into the next lower species is called its half-life. For example, the half-life of radium is about 1,600 years, meaning that if 1,600 years ago one had had one gram, one ounce or any other

quantity of radium, one half of it would now remain. This is not to be understood to mean that in the next 1,600 years the remaining half would entirely disappear—only one half of that half, or one fourth, would change and in the next 1,600 years one eighth, and so on. Pb is the final member and hence accumulates in all U and Th minerals. Uranium and thorium have very long life-periods—several billion years. If they changed more rapidly they would have disappeared long ago during the geological ages through which they have existed and would not now be found in nature.

If radium is then merely one of many similar radio-elements, why does it have such especial interest? The answer is an unusual one. It is one case where mediocrity excels. The importance of radium arises from the fact that it has a half-period of about 1,600 years, which is intermediate among half-periods distributed all the way from a short fraction of a second to billions of years. If the life of radium were very long, like that of uranium, it would be so inactive that it would take an inconveniently large amount to give off a required intensity of rays. It is not possible to use several carloads of ore in a clinic. On the other hand, if the life of radium were very short, like that of some of the other radioactive elements, it could not be retained long enough for it to be profitable to produce or purchase it. It is therefore its moderate span of life, neither too long nor too short, which makes radium valuable. Radium has only once been prepared in the form of the pure metal. It is more convenient to prepare and use it in the form of its compounds or salts—radium chloride, bromide or sulphate. All these when first prepared are white, like table salt, and in ordinary daylight look equally harmless, but after a few hours a darkening in color indicates that something unusual is taking place. This change in color is produced by the rays themselves, and has no especial significance, but on observing a radium salt in the dark a continuous will-o'-the-wisp glow is manifest, and if any part of the human body be exposed to it too long or intensively, a deep-seated injury like a burn will result a few days later, though no sensation of pain is experienced at the moment.

It was this experiment performed by Pierre Curie on himself which suggested the therapeutic use of radium, which has come to be of great value in the treatment of cancer and other diseases.

In such treatments radium is generally used directly in tubes containing its salts. This method exposes the radium to the danger of loss, accident or theft in the clinic. Occasionally patients have swallowed the tubes, necessitating an operation to save both the radium and the patient. The newer and better practice is to retain

the radium in the laboratory in solution and to collect from it a gas—radium emanation or radon—which has all the desirable radiating properties of the parent salt. Since this gas is fairly shortlived, it must be collected anew from the solution at short intervals—daily in the larger clinics. The gas is continually regenerated from the stock solution of radium and hence its loss would not be serious. The therapeutic use of radium has now become common in many of our larger hospitals, and by far the greatest proportion of radium that has been produced has gone into therapeutic use.

The only other important use of radium is that in the luminous paints, such as are used on illuminated watch and clock dials. The base of these paints is a specially prepared zinc compound called phosphorescent zinc sulphide, because it glows in the dark after exposure to light. Unfortunately, this afterglow from ordinary light will last only an hour or two, so that radium must be added to the paint to produce a continuous glow.

During the war, luminous paints came into very general use on wrist watches and other dials which had to be visible without disclosing a light to the enemy. An aeroplane control board has eight or more dials which must have a paint of high radium content to give sufficient luminosity for twilight flying, while it is too dark to see well, but before the eye has become sensitive. New uses for radium paint are continually being found, as on electric switches, push buttons, drop cord pendants, numbers on Pullman berths and theater seats, keyholes or on any object which it is desired to find or to avoid in the dark.

These luminous paints have a fairly long life—several years at least, but at best far too short to justify the use of radium with a half life of 1,600 years. The use of a similar radio-element obtained from thorium, called mesothorium, is preferable when it is available. Mesothorium is now substituted in part for radium in luminous paints, where, on account of its short life, it is far more suitable than in therapeutic use.

The production of radium on a commercial scale was first begun in Austria from the pitchblende of the Joachimstal Mine. Pitchblende is a black oxide of uranium, which, like most other uranium minerals, contains one part of radium to three million parts of its parent uranium. The Austrian ore was of such grade that it could be profitably worked, and prior to the world war two to three grams were produced each year from this source. The cost varied from $80,000 to $160,000 per gram.

Just about the beginning of the war, in 1914, the center of radium production was shifted to the United States, through the

development of a new uranium ore called carnotite. Carnotite occurs in fairly large quantity in certain sandstones in Colorado and Utah. Unfortunately, it is not a rich ore in radium content, and since it occurs in remote districts, where mining operations are expensive, the cost of producing radium from it was quite high. In spite of these difficulties the industry had a remarkable development, owing to the energy and courage of those who entered it before and during the war. The Standard Chemical Company, of Pittsburgh, was the pioneer and has to date produced more than half of the world's supply of radium. The United States Bureau of Mines was the next earliest producer in this country. Later the Radium Company of Colorado and the Radium Luminous Materials Corporation and several smaller companies entered the field. For several years the production in the United States from carnotite was on a large scale, ten to fifteen times that of Austria. In 1921, 35 grams were produced in the United States. During the war the price reached $125,000 and occasionally $135,000 per gram. After the war it became stabilized at $120,000, except for occasional sales of large quantities at lower prices.

A price of $100,000 for a half thimbleful of material seems on first thought fabulous and has been regarded by many as exorbitant. But when one considers that in order to produce one gram of radium, which would in the final pure state be about a half thimbleful, it is necessary to mine from 200 to 500 tons of ore, which frequently has to be packed on burros and then hauled 60 or 80 miles to a railway and then be shipped from 500 to 2,000 miles by rail, and that an equal weight of chemicals is consumed in the extraction of radium, not to forget the expense of labor and of a highly trained staff of specialists, a different idea is obtained. As a matter of fact, the price of radium has always been based on cost, quite as rigidly, if not more so, than for most mineral products.

About three years ago the discovery of a new source of high-grade radium ore in the Belgian Congo was announced by the owners, the Katanga Copper Company of Belgium. Owing to the high grade of the ore, which is principally pitchblende and kasolite, and to favorable conditions for mining it and for working it up in Belgium, the cost of production was lowered to a point at which American carnotite can hardly compete. The price was reduced from $120,000 to $70,000 per gram. The United States Radium Corporation, of New York, has been the only company to continue to produce from American carnotite. The Standard Chemical Company still maintains its medical service and sales organization for the distribution of the Belgian product. For a time, at least, American production is largely suspended.

Curiously, this drop of almost one half in the price has not stimulated sales of radium, but has had the opposite effect. In 1923 about 18 grams were sold, and in 1924 only about 10 grams. This is probably not attributable to saturation of the American market, but rather to hesitancy on the part of the prospective purchaser, fearing that his investment may be jeopardized by a further reduction in price. The Belgian Company has announced no definite future policy, but a further reduction in price does not appear to be immediately in sight, if at all. It is reported that the Belgian plant is now closed on account of over-production. Since the American market is the principal one for the sale of radium, it is believed our willingness to purchase will be the controlling factor. Apparently, the uncertainty of the situation brought about by the Belgian discovery is at present the only deterrent factor in the sale and use of radium.

EARTHQUAKES

By SIDNEY PAIGE

U. S. GEOLOGICAL SURVEY

EARLY in March there was felt in the northeastern United States an earthquake, the origin of which lies perhaps in Maine, perhaps in Canada. It was felt in New York City, in New Haven and at other places. Various accounts have appeared in the daily press—an excellent one in the New York *Times* of March 8.

Shortly before this quake occurred it was proposed that I broadcast a brief account of earthquakes. Let me heartily congratulate the managers of WCAP for arranging the recent shocks. Their advertising department is apparently 100 per cent. efficient, but their evident close association with the powers of darkness is very discomfiting. One hesitates to think what would happen should they propose a talk on hell fire and eternal damnation and advertise the subject with equal efficiency.

An earthquake is exactly what the word indicates—a quaking of the earth. The violence of the quake at any place is in general directly proportional to the violence of the disturbance at its origin and to the distance of the place from this origin.

It has long been recognized that certain regions of the earth's surface are particularly subject to earthquakes and that in certain other districts earthquakes rarely if ever happen. Between these extremes there are all possible degrees of earthquake visitation.

Furthermore, in a region or country that is subject to earthquakes (Japan, for example, or Italy) there are many districts

which are hardly ever visited by perceptible shocks. This fact in itself is sufficient to suggest that earthquakes have a very definite local cause. Broadly viewed, the principal earthquake regions of the world are situated along certain continental borders or in other regions where we know geologic changes in connection with mountain growth are relatively rapid and now in progress. Thus all around the Pacific Ocean there is a succession of seismic areas beginning with the East Indies and passing north and east by way of the Philippines, Japan and Alaska and then south along the west coast of the two Americas. Another well-marked region begins in the west of Europe and passes east through Sicily, Italy, Greece, Syria, India and Central Asia. The West Indies constitute a district which may be taken along with Central America. In these regions are contained practically all the known localities subject to pronounced earthquake activity. Note that the phrase "*pronounced* earthquake activity" is used, for earthquakes do occur in other regions but far more rarely. If you examine a globe of the earth you will find that the great earthquake zone that follows the Pacific border is almost an arc of a great circle. In reality, you do not *cross* the Pacific in going to Japan—you *follow the coast* along an arc that is remarkably straight, considered on a large scale, from the southern tip of South America to the East Indies and Australia. The second earthquake zone likewise has this characteristic of nearly following a great circle, though its direction is quite different from the first. Both of these great earthquake belts are very *mountainous* belts, are major topographic features of the earth's surface, and are regions of great instability of the earth's crust. At many places these high mountains are bordered by oceanic deeps, and it is within this zone between ocean deep and high mountains that adjustments of the crust of the earth are now taking place.

Perhaps 99 per cent. of earthquakes that are felt are due to movements of the earth's crust along faults, which are really nothing but cracks—that is, they are due to adjustment in the equilibrium of the crust as a whole, along lines of weakness such as have just been described. These zones of weakness (where faulting—that is, breaking—takes place) may be attributed to stresses accumulating during a vast extent of time and caused by the force of gravity constantly seeking to adjust the balance of an unequally weighted crust. Just one example of how this balance is being slowly but continually upset: You may readily see that the continual transfer of material by the Mississippi River from its broad drainage basin to the delta at its mouth is necessarily bringing about a redistribution of weight on the outer crust. Ultimately there must be re-

sponse to the weight of such a deposit. If the globe is actually shrinking, due to transfer of heat or changes in density, obviously the outer crust will be constantly deformed. The complex folding and faulting of the surface rocks in many places supports this view.

Active volcanoes are formed at many places along the great belts of weakness just referred to, but they should be thought of as *results* of the adjustments going on and not as the cause.

How is the shock of an earthquake transmitted? The rocks are strained until the limit of their elasticity is reached, when they suddenly break—either along an old fault or on a new one. The friction along the fault plane is enormous, and as the surface on one side drags against the other vibrations are set up that travel outward as a succession of waves. Likewise the actual elastic rebound of the earth block on the two sides of the fault starts a wave that travels outward. The speed of these waves is great and the surface of the ground is actually set in violent motion. It is this motion that we feel as the shock, and in general the nearer one is to the origin of the disturbance, the more violent the shock. A violent shock may be recorded on delicate instruments completely around the globe.

If a shock originates by vertical faulting beneath the deep sea, a water wave that travels with great speed starts outward. Such a water wave in approaching the shore, over a gradually shallowing bottom, may attain great size and cause great damage to towns built at sea level. The sea may be withdrawn at first but may return with great violence. Such waves have proved disastrous on the west coast of South America, at Lisbon, Portugal, and at many other places.

The destructive effects of a great earthquake in a thickly populated district are appalling. The disaster is often intensified by fire, and if the district is exposed to the sea, great waves may add to the horror of the occasion. In the city of Lisbon, Portugal, sixty thousand people were killed in less than five minutes by the collapse of nearly all buildings, and an hour later great waves from the sea thirty to sixty feet high inundated the city, adding to the destruction. Lima, Peru, was destroyed by an earthquake, and on the evening of the same day the sea rose in a wave eighty feet over the port of Callao, on the coast. Out of twenty-three ships in the harbor, nineteen were sunk and four others were carried far inland.

The recent earthquake in Japan (September, 1923) was accompanied by fires in Yokohama and Tokyo that were the most disastrous recorded in human records. The property loss is estimated in billions of dollars and lives in hundreds of thousands.

Slight earthquakes leave little or no trace on the surface of the ground; violent earthquakes produce startling changes with great suddenness. The San Francisco earthquake was caused by the sudden rupture of the earth's crust along a fault zone known as the San Andreas rift, for a distance of 270 miles. The fault unaffected by movement can be traced much farther. The displacement was such as to cause the country on the southwest side of the rift to move northwestward relatively to the country on the northeast of the fault line. The movement was largely horizontal and in places as great as twenty-one feet. As a result all the fences, roads, railways, bridges, tunnels, dams, pipes and other structures which cross its path were dislocated. Inasmuch as the movement of the earth which caused the fault was not confined to its immediate vicinity, but was distributed over a considerable belt of country on either side of the rupture, the latitude and longitude of a large portion of the coast ranges of California were changed, and resurveys have been necessary.

In the recent Japanese disaster of 1923 marked changes of level occurred along the coasts of Sagami and Tokyo bays, and soon after the earthquake a resurvey was made of Sagami Bay. It revealed three areas of depression and three of elevation. The maximum subsidence was found to be 1,554 feet, the maximum elevation 810 feet. Some of this change, however, may have taken place before the earthquake.

It is reported that in the whole earthquake area 128,266 houses completely collapsed, 126,233 half collapsed, while 447,128 were burned and 868 were swept away by the sea waves. Along the shores of Sagami Bay the percentage of houses that collapsed was extraordinarily high—84, 95, 96 and 97 per cent. at four different places. So complete destruction was due in part to the nature of the sites on which these towns were built. In Tokyo the intensity of the shock was three times as great on soft soil and "made ground" as on the harder ground elsewhere. The effects of this great and sudden shock on different kinds of buildings provide useful warnings for the future. Brick buildings crumbled down at once into ruins; wooden buildings, of which so large a part of Tokyo was built, withstood the shock fairly well but were an easy prey to the fires that followed. The modern steel-brick buildings offered a stout resistance to both earthquake and fire, and it is natural to conclude that the new Tokyo and Yokohama will, as far as possible, be cities of steel-brick houses.

Earthquakes can be predicted only in general terms, and the soundest basis for this prediction is the statistical record of past disturbances. For instance, in Japan, where on the average there

are one or two quakes every day, it is not difficult to predict an earthquake for the country as a whole. But to indicate exactly where and when it will occur is at present impossible. In most of the eastern United States, therefore, where earthquakes are so rare, even an approximate guess as to time or locality can not be made. And it is equally hazardous to assert that a disastrous quake will never occur. In other words, the earthquake risk varies greatly from region to region, and in respect to this risk the eastern United States is very favorably placed but is certainly not immune from the possibility of a severe shock, which if occurring in a densely populated district might prove disastrous.

Interest in earthquakes in this country was greatly stimulated by the San Francisco disaster, although in Japan the subject had been seriously studied for many years. The engineering aspects of the subject are now receiving much attention. The best types of foundation, the best distribution of weight, the best types of construction are all subjects of inquiry. Protection of water and gas mains is vital. Important aqueducts and dams in the West are being studied with earthquake possibilities in mind. The faults of California are being mapped with respect to their past and probable future activity.

In closing I wish to call attention to certain social aspects of the earthquake problem. There is nothing to be gained by minimizing the earthquake risk in regions where the risk is high. Attempts to suppress information or discussion or study, on the ground that business will be adversely affected, are not only shortsighted but useless. Pressure of increasing population is so great and is growing so rapidly that all places favorably located for commerce will always be thickly populated, and thus business will always be carried on. Tokyo and Yokohama will be rebuilt. Therefore business men should strongly support all earthquake inquiry. Scientific earthquake investigation will ultimately properly evaluate risk, as statistical data accumulate and as geologic investigation continues. Engineering skill will improve construction, structures will be more favorably placed with respect to foundations, and materials will be better adapted to the stresses that they must withstand under an earthquake shock.

The word seismology, meaning the study of earthquakes, is derived from the Greek word for earthquake. Instruments to detect and measure the intensity and nature of earthquake movement are called seismographs. Such instruments are widely distributed over the world. The mechanical problem to be solved in order to measure earthquake motion is to maintain a point that will remain *steady* while the earth vibrates. Then a suitable pencil attached to

the steady point will register the vibration of the earth, if a suitable surface is provided on which this vibration can be recorded. Books have been written on methods of doing this. There are many such instruments in the United States and in other parts of the world.

With a number of these instruments supplemented by other data it is possible to locate very accurately the origin of earthquake shocks. The practical and theoretical value of the accumulating records in seismological laboratories, interpreted as they are with ever-increasing knowledge, is very great. Much is being learned that will at least alleviate earthquake disaster, and much is being learned regarding the constitution of the deeper portions of the earth.

The Seismological Society of America, with headquarters at Stanford University, California, is doing splendid work in this connection.

WHERE ARE THE STARS?

By Dr. C. G. ABBOT

SMITHSONIAN INSTITUTION

We see less than 5,000 stars with the naked eye. On clear moonless nights, a cloudy belt called the Milky Way encircles the heavens. A telescope shows that this is really a multitude of stars. It lies in the plane of greatest extension of our heavenly host. Although only three or four thousand stars can be seen by the naked eye, the telescope proves that there are really thirty or forty billion of them, ten times as many, for instance, as there are dollars in the budget of the United States government, and twenty times as many stars as there are living people in the world. They do not extend indefinitely, but lie in a limited extent of space of the general shape of a watch or lens. How big is it?

To know that, we have to find a way to measure tremendous distances. We begin with the sun. The sun is a star. If he were carried away to the next nearest star, Alpha Centauri, which is visible in South America, but not in the United States, the sun would be a twinkling point of light, and only as bright as Altair. We have to know his distance to learn more about the distances of the others.

There are many ways to measure the sun's distance. They agree so well that there can be no doubt that we know it within about a tenth of one per cent. I shall tell you first about the velocity of light. Dr. Michelson, now of Chicago, and a winner of the Nobel prize, was a midshipman in our navy when a young man. He car-

ried out measurements of the velocity of light here in Washington with the late Professor Simon Newcomb. They used a mirror revolving very rapidly at a measured speed. A beam of light, reflected by the moving mirror, traveled across the Potomac River, was reflected back, hit the moving mirror a second time, and was reflected towards the original source. But while the light traveled, the mirror turned. So the reflected beam did not return exactly to the source, but a little to one side. From this displacement, they computed the velocity of light. It came out 186,330 miles per second.

The planet Jupiter revolves round the sun like our earth. Jupiter, as you may see with a small telescope, has several moons. These moons and Jupiter shine by reflected sunlight just as our earth and its moon also do. When one of Jupiter's moons gets behind the planet, it is eclipsed, just as our moon is when it gets behind our earth, out of sight of the sun. Astronomers find that the eclipses of Jupiter's moons take place 16 minutes 37 seconds later when the earth is on opposite sides of the sun from Jupiter than they do when we are on the same side. You will see at once that the eclipses of Jupiter's moons occur 16 minutes 37 seconds later because the light that tells us when they occur has to travel just the diameter of the earth's orbit further at one of these times than at the other.

But in 16 minutes 37 seconds there are 997 seconds, and light travels about 186,000,000 miles. So the sun is half that distance, or about 93,000,000 miles away. This is not the best way to measure the sun's distance, but perhaps the easiest to understand. All the other good methods give nearly the same result.

When a surveyor measures a very long distance, he takes two stations a convenient known distance apart, and setting his instrument at both, he measures the angles of his triangle whose three corners are the two home stations and the distant point.

In applying this method to measure the distances of the stars, the diameter of the earth is too small a base line. But as the earth goes round the sun in twelve months, it occupies stations 186,000,000 miles apart in January and July. Surely that immense distance between the home stations ought to be enough. It answers for only a few hundred among the stars. With the very nearest star to the sun, Alpha Centauri, the total angle it appears to pass over as we swing from one side to the other of the earth's orbit is only 1.6 seconds of arc. This is about the same as the width of a telegraph wire seen a half mile distant. The distance of Alpha Centauri is about twenty-five millions of millions of miles. It takes light, traveling 186,000 miles a second, more than four years to come to us from Alpha Centauri, but only eight minutes to come from our sun.

To measure star distances in this way, astronomers now use photography exclusively. They photograph the chosen star against his background of very faint stars, which are many times as far away. Similar photographs are made at intervals of about six months. By exact measurements of the distances of the chosen star from his faint neighbors, the little displacements due to the earth's motion are finally determined. But if these displacements are much less than 1/100 second of arc, they are too small to measure. Therefore, there can be no certainty by this surveyor's method as to star distances that require of light more than five hundred years to travel.

This does not begin to get us to the ends of our starry system. Nevertheless, just as the distance of the sun gives a starting point towards the nearer stars, so their distances give a starting point for the rest. It has been a great boon that men like Dr. Schlesinger, of Yale; Dr. Mitchell, of the University of Virginia; Dr. Van Maanen, of Mount Wilson Observatory, and others have conferred by making nearly 2,000 such star-distance measurements in the last fifteen years.

Our sun, with the earth, the moon, all the planets and their moons, is traveling about twelve miles a second towards the bright northern star, Vega. All the other stars like the sun are traveling, too, but in all directions. Refined measurements show these so-called proper motions of the stars, but we have to wait many years to measure them accurately. A proper motion as large as a second of arc in a year is very rare. Still thousands of the stars' proper motions are accurately known. Now it will be clear that if a star which seemed to move a second of arc per year was carried twice as far away from us, his motion would then seem to be only a half second per year. So the proper motions diminish in direct proportion as the distances increase.

If, now, we consider all the stars whose distances have been measured, we shall be able to find the average proper motion which suits a standard distance. Then, let us group all the stars according to apparent brightness. If a large group of stars has an average proper motion ten times less than the average proper motion corresponding to the standard distance, we know that stars of that group are ten times the chosen distance away. There are several pitfalls to be avoided that I haven't time to explain, but I'm sure you all catch the idea. In that way Professor Kapteyn and his successor have found for us the average distances of a group of stars of given brightness.

Working by wholesale like this, we can go as far as we please, even to stars so distant that light requires many thousands of years

to come to us from them. This is the way the shape of our star system has been worked out. It is found to be a flattened disk, like a watch or a lens, perhaps 10,000 light-years thick, and 100,000 light-years in diameter. Still it is not satisfying to have to work altogether by wholesale. We need many individual star distances, too.

About ten years ago, Dr. Adams, of Mount Wilson Observatory, and his colleagues discovered a powerful method based on the use of the spectroscope. The stars give rainbow-colored spectra with thousands of dark lines crossing the band of color. Some of these dark lines, as Dr. Adams found, vary in their intensity of shade according to the absolute brightness of the star that produces them. By absolute brightness, I mean the rank a star would have among the others if they were all at equal distance. You will ask how Dr. Adams could know the absolute brightness. He could know it only for stars whose distances had been measured. But there were enough of them to show exactly how these sensitive spectrum lines change, depending on absolute brightness.

Very well. Whenever he observed the spectrum of a star, he measured the intensity of these sensitive spectrum lines. That proved how absolutely bright the star was. Comparing absolute brightness with apparent brightness, he could calculate exactly how far away the star must be. The great beauty of this method is that it makes no difference in its percentage accuracy how far away a star is, provided the spectrum can be well observed. With Adams's method, star distances of many thousand light-years are measurable.

Now we must mention another method very limited in scope, but highly important. There is a kind of stars tremendously bright, and more massive than our sun, which vary in their brightness. They go through a cycle of changes in from one to fifty days. The star Delta Cephei, in the northern constellation of Cepheus, is one. Because of this, these are called Cepheid variables. The distances of a good many Cepheids are known. Dr. Shapley, director of Harvard College Observatory, found that the average absolute brightness of the Cepheid variables was closely related to the period of a full cycle of variation. He was able to draw a curve giving absolute brightness against period of variation. With this curve, one needs only to know that a star is a Cepheid, and the absolute brightness can be found immediately from observing the period of variation. From this and the apparent brightness comes the distance. As the Cepheids vary in brightness in a very special manner, they can be recognized very readily.

Besides the stars, there are in the heavens cloud-like objects called nebulae. Only a few of them can be seen by the naked eye,

the largest of these being in the constellation Andromeda. Several hundreds of thousands of nebulae are visible to great telescopes. It has been a question for over a century what sort of objects they are. Sir William Herschel suggested them to be island universes, that is, other star systems separate from ours. Dr. Hubble, of Mount Wilson Observatory, has proved it.

He photographed the Andromeda nebula. At the outer part, he was able to resolve the cloud-like object into a multitude of tiny stars. They were all ten thousand times too faint to be seen by the naked eye. He found some of these stars to be Cepheid variables. By noting their periods, he found their absolute brightness. Comparing with the apparent brightness, he worked out their distance. They all agreed in giving the distance approximately a million light-years. The light by which we see the Andromeda nebula started towards us before the glacial period and before there were any men on earth. The nebula lies about ten times as far from us as any stars in our system. It is another galaxy of stars. If this is so for the Andromeda nebula, doubtless it is also the case for many others. Indeed, Dr. Hubble has already found others equally distant. Many of them, which are mere points of light, may require a billion years for their light to reach us.

Consider, if you please, about how important a single human individual is. He is one of a race of some two billions, which changes every generation, on an earth which is a hundredth part as large as the sun. The sun is one of thirty billions of stars, which altogether make but one out of hundreds of thousands of galaxies of stars. Some of these galaxies are probably so far removed that the light which reveals them started towards us before the world began.

I thank you. Good night.

THE STATE OF SCIENCE IN 1924[1]

THE WATER IN THE ATMOSPHERE[2]

By Dr. G. C. SIMPSON, F.R.S.
DIRECTOR OF THE METEOROLOGICAL OFFICE

THE dictionary definition of "saturation" is "the state of a body when quite filled with another," and it is usual to think of saturated air as air which is full of water vapor to such an extent that further water can not be added without condensation taking place. This, however, is a wrong conception, for there is no limit to the amount of water vapor which air can contain at any temperature, provided that it is perfectly pure, except that ultimately the molecules of vapor will be so near together that there will be no distinction between vapor and liquid.

We will describe air as saturated when the water vapor it contains is in equilibrium with a flat surface of pure water at the same temperature. This will define the saturation pressure at each temperature, and relative humidities will be given as percentages of this saturation pressure.

It is well known that water can be cooled below its freezing point without becoming ice, and therefore water and ice may exist side by side over a large range of temperature. But the vapor pressure which is in equilibrium with ice at a given temperature is lower than that which is in equilibrium with super-cooled water at the same temperature; that is, air is in equilibrium with ice at a relative humidity below 100 per cent. Thus, according to our definition of relative humidity, the water vapor in air may be in equilibrium with water over a large range of relative humidities according to the physical state of the water present.

CONDITIONS FOR CONDENSATION

It was in 1880 that Aitken first showed that condensation does not necessarily take place in air when its temperature is lowered below that at which the water vapor it contains is sufficient to saturate it (dew point). He expanded carefully filtered air and found that no fog formed even when there was considerable supersaturation. Aitken concluded "that vapor molecules in the atmosphere do

[1] Prepared for the Handbook to the Exhibit of Pure Science, arranged by the Royal Society for the British Empire Exhibition.

[2] Abstracted from *Nature*.

not combine with each other, that before condensation can take place there must be some solid or liquid nucleus on which the vapor molecules can combine, and that the dust in the atmosphere forms the nuclei on which the water vapor molecules condense."

Aitken invented a most ingenious instrument, easy to work and very transportable, by means of which it is possible to count the number of nuclei present in the air. Tests made with this instrument show that nowhere is air free from nuclei. Their number is seldom less than 100 per cc, while in most country places the nuclei rise to thousands, and in cities such as London and Paris the number may be so great as 100,000 to 150,000 per cc.

The general explanation of these observations is as follows. If there were no dust particles present the drops of water would have to be built up from aggregates of water molecules; if a few molecules met together by chance, they would form so small a drop that it could not exist unless there was large supersaturation. If, however, there were dust particles present the molecules of water would be deposited on them, and the radii of the initial drops would be so large that little supersaturation would be required to maintain them.

This explanation appeared to satisfy every one for a long time. In 1912, however, Wigand found that even when he created large clouds of dust he could not find any increase in the number of nuclei in his condensation apparatus. Apparently Aitken's instrument does not measure the number of dust particles present, but the number of hygroscopic particles, and meteorologists are now of opinion that condensation commences on these hygroscopic substances.

Köhler, working in Norway, is tempted to contend that sea-salt provides these particles. It is, however, not necessary to go so far as this, for there are many other sources of hygroscopic substances. Lenard and Ramsauer have shown that sunlight—probably only the ultra-violet part—acts on the oxygen, nitrogen and water vapor of the atmosphere, producing very hygroscopic substances.

Large quantities of material capable of becoming condensation nuclei, however, are produced by all processes of combustion. Thus the household fires and factory chimneys of centers of industry produce vast quantities of nucleus-forming material, chief of which is sulphurous oxide. This, when illuminated by sunlight in the atmosphere, is a very hygroscopic substance capable of causing condensation in unsaturated air. It is estimated that in England something like 5,000 tons of sulphur are burnt each day in coal fires, giving enough sulphur products to pollute the atmosphere from Land's End to John o' Groat's. Other products of combustion are also

hygroscopic; thus it is not surprising that air from large industrial centers contains enormous quantities of nuclei.

When the temperature of the air is below the freezing point, it is inconceivable, owing to the small amount of vapor present, that condensation will take place by the fortuitous meeting of molecules; some kind of nuclei therefore will be necessary.

When sledging in the Antarctic with Captain Scott in 1911 we became enveloped in a fog during sunshine. On the fog opposite the sun we saw a white bow in the position usually occupied by a rainbow. This phenomenon can only be explained on the assumption that the fog was composed of small spheres. But the temperature was −29° C. (−21° F.) and almost a dead calm existed at the time; hence these drops could not have formed at a high temperature and then been super-cooled. The only explanation appears to be that in the clear air of the Antarctic, where there are no "dust" particles suitable for condensation available, there are plenty of hygroscopic molecules of some sort.

Haze

Perfectly pure air is almost completely transparent to visual light waves, and if the air were always pure we should see distant objects through air almost as clearly as through a vacuum. But there are always more or less particles of foreign matter present. The action of these particles is twofold: first, they reduce the amount of light reaching the eye from distant objects; and, secondly, in the daytime they scatter the general light of the sky and so send to the eye extraneous light which reduces the contrast between distant light and dark objects on which visibility depends. Generally this foreign matter consists of a mixture of solid ponderable particles and hygroscopic molecules. In perfectly dry air the latter would be practically invisible, but when loaded with water in a humid atmosphere they add to the obscurity of the atmosphere.

Haze is due to this kind of obscurity, and varies in intensity from the slight obscurity of polar regions, which depends almost entirely on the hygroscopic particles, to the dense obscurity of a dust storm in tropical regions, which is due almost entirely to solid particles.

Mist

If the temperature falls below the dew point, the hygroscopic particles are sufficiently large to form excellent nuclei for condensation, and relatively large amounts of water are deposited for small falls of temperature.

Real condensation has now commenced and the obscurity changes from that of haze to that of mist. The whole process of

the formation of haze and mist is continuous, but they are fundamentally different, for haze owes its origin to foreign matter and the small amount of water associated with hygroscopic nuclei, while mist is due to an actual precipitation of water from vapor to liquid.

Fog

There is no fundamental difference between mist and fog: in most cases fog is only a dense mist, and the density at which mist becomes fog is a matter of definition. It is now the practice of the London Meteorological Office to limit fog to the obscurity in which objects at 1 kilometer are not visible.

When mist and fog are formed in fairly clear air they are white. On the other hand, if the air contains a large quantity of impurities, such as carbon particles from imperfect combustion, the mist particles absorb the impurities and become themselves dark-colored. In this way are formed those dense fogs in London which are likened to pea soup. It was originally thought that the density of a London fog was due to the fact that the smoke of the city provided an unusually large number of nuclei on which condensation could take place, thus offering a temptation to the air to deposit its moisture which it could not resist. As a matter of fact, there are always sufficient nuclei in the purest air in England to allow of the formation of fog whenever the meteorological conditions are suitable.

The relationship between smoke and fog is peculiar, and may be said to be accidental. The meteorological conditions which are necessary for the formation of fog are such that while they last, smoke can not get away either vertically or horizontally from the place of its origin. Thus during a fog practically all the smoke which London makes is kept over it and within a few hundred feet of the ground. This smoke, combined with the deposited water, can, as we all know, produce such an obscurity that midday is as dark as midnight. The total abolition of smoke from London would not reduce the occasions on which mist and fog occur, but many fogs would remain mists, and we should never have a "London particular." The fogs of London are caused almost entirely by loss of heat from the lower layers of the atmosphere into a clear sky above. The air radiates its heat, its temperature falls, and condensation takes place. Other methods of fog formation, such as the mixing of warm and cold air, are of secondary importance and never give rise to more than patchy local mists or light fogs.

Clouds

When air not saturated rises in the atmosphere its temperature is reduced by about 1° C. for every 100 meters of ascent. When

the ascent is carried far enough the dew point is reached, after which any further rise will cause condensation on the nuclei present. As the ascent is carried beyond the point of condensation more and more water is deposited, with a consequent increase in the size of the drops. This is the manner in which clouds are formed, and there are very good reasons for saying that it is the only way. Thus there is a fundamental difference between the method of formation of clouds and fogs: fogs form without any ascent of the air, while clouds are never formed without it. Thus it is not correct to describe clouds as fogs of the upper atmosphere.

The very sharp line of demarcation between the air under a cloud and the cloud itself needs explanation. The hygroscopic nuclei collect more and more water around them as they rise with the ascending current, owing to the increase in relative humidity. But when saturation is reached they are still very small, and produce little obscurity in the air. Such drops, however, need only 1 per cent. supersaturation to grow. Moreover, they are unstable, for as they grow they need less supersaturation. Thus, as soon as the air is sufficiently supersaturated to be in equilibrium with the nuclei, the slightest further rise causes the drops to grow very rapidly to the size in which they are in equilibrium with saturated air. The height at which this change occurs is the height of the base of the cloud.

Rain

When bodies fall through a resisting medium, such as air, they more or less quickly reach such a velocity that the resistance of the air equals the pull of gravity, after which they fall with a constant velocity, which is different according to the density and shape of the falling bodies.

Experiments have been made to determine the rate of fall of water drops through air at atmospheric pressure, and they show that the small drops in clouds would fall only at the rate of a little over a centimeter a second. As the drops get larger the rate of fall tends to a constant value of about 8 meters a second, while drops half a centimeter in diameter have the most rapid fall. Larger drops fall more slowly; for instead of retaining the shape of spheres they became flattened out, thus presenting an increased resistance to the air through which they are falling. When the size of the drop is such that, if it were not flattened it would have a diameter of about half a centimeter, the drop becomes very unstable, and all drops larger than this quickly break up into a number of smaller drops, which of course fall more slowly. This means that raindrops can never fall through air at a greater velocity than 8 meters

a second. Small drops fall slower than this, and large drops flatten out as soon as they are falling at 8 meters a second, and then soon break up into smaller drops.

W. H. Dines has found that in Europe the quantity of vapor in air is always very small. If the whole water vapor in the atmosphere on an average summer day were precipitated it would only give a total rainfall of 0.80 in. The greatest amount ever measured on a summer day in Europe would only give 1.5 in. of rain, and, of course, the quantity is much less in winter. Rainfall of several inches of rain in the course of an hour or so such as occurs in the tropics is due to ascending currents which carry with them their own water vapor to supply the rainfall. Ascending currents up to many meters a second are possible, and do occur in the atmosphere. Let us think of air rising at about 10 cm per second, which is the order of the upward velocity of the air in depressions. At a certain height cloud particles form as already described. These have a radius of about 0.001 cm and fall relatively to the air at 1.3 cm per sec.; hence they are carried upwards with the air, but the base of the cloud remains at the same height because new cloud particles are constantly being formed at that height. As the air rises the cloud particles grow in size, because water is being condensed on them, and they lag more and more behind the air. Drops with a radius of 0.002 cm are falling as rapidly as the air is rising, and therefore remain stationary, while drops of 0.007 cm are falling at the rate of 1 meter a second, and therefore fall through the rising air and appear at the earth's surface as rain. This process will continue so long as the ascending currents continue, and in this way we get the continuous steady rain with which we are so familiar in this country.

When the upward velocity of the ascending air becomes greater than 8 meters a second, no water can fall through the ascending air for the reason already explained. All water condensed in such an upward current—and it will be a very large amount—is carried upwards until the upward air velocity falls below 8 meters a second, as it is bound to do at some height owing to lateral spreading out. Here water accumulates in large amounts. It is the sudden cessation of the upward velocity in such an ascending current which gives rise to the so-called cloud-bursts; for when the sustaining current stops, the accumulated water falls just as though the cloud had literally burst.

The accumulated water while it is suspended in the air is constantly going through the process of coalescing into large drops, which at once become deformed and broken up again into small drops. Every time a drop breaks there is a separation of elec-

tricity, and this is probably the chief source of electricity in a thunderstorm. This explains why thunderstorms are associated with heavy rainfall and do not occur in polar regions, where there is no rain.

Hail

Let us consider a region in the atmosphere through which there is an ascending current of air. The air is supposed to have a temperature of 20° C., and a relative humidity of about 50 per cent. at the ground. As the air rises, at first its temperature is reduced by 1° C. for each 100 meters of ascent. Hence by the time it has risen 1,000 meters its temperature will have been reduced to 10° C., and it will have reached its dew point. Here the cloud level begins. As it rises still further its temperature continues to decrease, but not so rapidly as before, because the condensation of water vapor releases the latent heat of vaporization. It reaches 0° C. at a height of 3,000 meters. Hence the region between 1,000 and 3,000 meters contains only drops of water. As the air rises above 3,000 meters the temperature falls still lower, but the water particles do not freeze at once, they remain super-cooled. We may assume that at −20° C., which is reached at about 6,000 meters, the super-cooled drops solidify and the remaining part of the cloud above this level is composed of snow alone.

There will not be a sharp division between the region of super-cooled water and the region of snow. For a certain distance ice crystals and super-cooled water will be mixed together. Such conditions are very unstable, the ice particles grow rapidly, and, if the ascending current is not too large, they will commence to fall. It has, however, to fall through 3,000 meters of super-cooled water drops, and in doing so grows appreciably in size. As each super-cooled water particle strikes the ice it solidifies, and also imprisons a certain amount of air, so that by the time the ice particle reaches the bottom of the super-cooled region, it is simply a ball of soft white ice.

If the descent through the super-cooled region has been fairly rapid, the temperature of the ice ball will be considerably below the freezing point when it arrives in the region where the temperature is 0° C., and the cloud particles are not super-cooled. As it continues its way downwards it receives a considerable addition of water: in the first place by direct deposition, because it is colder than the air; and, secondly, by collision with the water particles. This water covers the surface of the cold ice ball with a uniform layer of liquid which quickly freezes into clear solid ice, with little or no imprisoned air. Finally, the ice escapes from the bottom of the cloud, and falls to the ground as a hailstone.

When hailstones are split open to show their internal structure, we can nearly always see the inner soft white mass of ice which was collected while the stones were in the super-cooled region, surrounded by a layer of clear transparent ice formed by the freezing of the water deposited when the stone was passing through the non-super-cooled region.

Hailstones are formed only during thunderstorms, when violent ascending currents of air occur. Thus, while the hailstone is growing in size, its rate of fall may well be less than the upward velocity of the air. All the time, however, it will be moving relatively to the air, and its effective height of fall will be great. This would enable it to collect water, and so would account for the large size often attained by hailstones. Moreover, such an ascending current is not steady. Just as there are gusts and lulls in horizontal winds, so there are increases and decreases in the velocity of ascending currents. Thus a hailstone which has penetrated into the lower part of the cloud might be blown upwards and so go through the whole process again. In this case we should have a layer of white ice deposited around the clear layer, around which again there would be another layer of clear ice. This process might be repeated indefinitely, giving several concentric layers of clear and white ice, and a broken stone would have the appearance of an onion. Such cases are not at all uncommon.

For the formation of hailstones two conditions must be fulfilled:

(*a*) The clouds must extend through a great vertical height so that the three regions of water particles, super-cooled particles and snow are extensive and well developed.

(*b*) There must be violent ascending currents, otherwise the stones would fall too rapidly to grow to a large size.

These conditions are best fulfilled in warm regions, for there violent ascending currents are most easily developed, and the condensation starts at a relatively high temperature, so giving regions of water particles and super-cooled water particles of great depth. These are the reasons why hailstones only occur during the summer in temperate regions, and why the most violent hailstorms and the largest hailstones are found in tropical regions.

Soft Hail

The hailstone receives its coat of clear transparent ice in the region between the bottom of the cloud layer and the zero isothermal. If this region is much reduced, as when the temperature at the ground is low, the hailstones are relatively small, and consist only of the soft white balls appearing in the center of the more complete hailstones. Falls of soft hail of this nature are quite common in the winter in Europe. The temperature of the ascend-

ing current is so low that the freezing point is reached almost at the bottom of the cloud, so the hail falls almost immediately out of the region of super-cooled water particles, and has no opportunity for building up a layer of transparent ice.

Snow

Snow which forms over an ascending air current in which water particles first form will probably have solidified cloud particles for nuclei. Whatever the nuclei may be, as soon as the initial crystals are formed further condensation takes place exactly as in the precipitation of water, but the vapor condenses directly into the solid state without first going through the liquid state. The crystals of water are hexagonal prisms. Having once started, the crystals may grow either along their central axis, giving rise to long thin prisms, or along their six axes to form hexagonal plates, showing all the wonderful shapes that this form of crystallization can take.

In cold regions the crystals are small, because there is little water vapor present from which they can grow. In the Antarctic during the winter, when the temperature was always near or below 0° F., only the smallest crystals were seen, so small that they were almost like dust.

When crystals form at temperatures near the freezing point they grow to their largest size. When the air is full of large crystals frequent collisions take place. The crystals become interlocked and bundles of many separate crystals are formed; these produce the ordinary snowflakes which, on account of their size and weight, fall relatively rapidly. It is to these latter that the term snow should be applied.

WEATHER FORECASTING

By Lieutenant-Colonel E. GOLD, D.Sc., F.R.S.

This note treats only of weather forecasts for relatively short periods and leaves entirely aside forecasts of the character of seasons or years. Broadly speaking, there are three processes which a weather forecaster must take into account in his prediction.

(*a*) The travel of weather from one place or region to another.

(*b*) The development of weather in moving air.

(*c*) The development of weather at a place or in an area consequent upon orographical features, such as hills or coast-lines.

Hills may produce cloud and rain; they may get snow when lowlands get rain; they may be in fog when the lowlands are clear; they may get gales when the lowlands get only fresh winds. At the

coast, temperature may be low in summer when it is very hot inland, or mild in winter when there is frost inland; there may be fog in summer when it is clear inland, or thunderstorms in winter when there are none inland. The coast-line is also a line of discontinuity so far as the resistance to atmospheric motion is concerned, and on that account it modifies the normal development of a cyclone.

The meteorologist at a central institution is better situated for dealing with the problems presented by (*a*) and (*b*) than a meteorologist at a local sub-office; but the latter has a very definite advantage in regard to (*c*) so far as the locality in which he is situated is concerned.

The idea underlying the method by which the problem of forecasting has been attacked is that the problem is one of mathematical physics, and that if we knew exactly what the physical condition of the atmosphere is at a given instant we could, theoretically at least, deduce what the conditions would be at subsequent times. Accordingly as much information about the weather existing at a given instant at different places over as wide an area as possible is collected rapidly at a central institute.

The actual problem can not be solved in exact mathematical fashion; but its explicit formulation and the application in present-day forecasting of the general mathematical and physical principles involved in the solution of the idealized problem do mark a definite advance beyond the pure empiricism of the earlier forecasters.

The organization in Europe by which the collection of information is made has grown rapidly since the war. In each country the observations from a selection of stations are issued by wireless telegraphy according to a prearranged time-table; these issues are received at the Air Ministry, and the observations are plotted on maps to enable the forecaster to get a rapid view of the existing situation. This is done three times daily (7 A. M., 1 P. M. and 6 P. M. Greenwich time), and a smaller collection of information is also made in the night (1 A. M. Greenwich time). The information from each observing station includes pressure (barometer); temperature; humidity; direction and force of the wind; existing weather and general character of the weather since the preceding report; form, amount and approximate height of cloud; visibility or distance at which objects can be seen; and the manner in which the barometer has been changing in the preceding three hours.

Early Forecasting

The dominant idea in British forecasting used to be the travel of weather, and efforts were mainly directed to discovering how the path of weather could be foretold. It was found from the earliest

studies of synoptic weather charts, some fifty years ago, that the two outstanding features were cyclones or regions of low barometer, and anti-cyclones or regions of high barometer. Broadly, the first were associated with windy and wet weather, and the second with quiet dry weather. If the coming of windy and wet weather can be forecasted correctly, then, *ipso facto,* quiet and dry weather can also be forecasted. It seemed therefore fundamental to understand the distribution of wind and weather in the area of a cyclone, and this was formulated by Abercromby some forty years ago in a generalized way. Upon this and the analysis by van Bebber of the paths of depressions at different seasons, forecasts were mainly based. A cyclone was indicated by readings of the barometer, its path and speed of translation were estimated, and the sequence of weather to be expected at any place could then be written down more or less accurately.

It was indeed recognized that deformation of the cyclone might occur, and that a bulge of the isobars, usually at the southern extremity, might have the features of wind and weather appropriate to a cyclonic entity without necessarily having the closed isobars, although in some cases it might have them, too. Such bulges came to be called secondaries. It was also recognized that cyclones differed considerably among themselves in regard to the actual distribution of weather, but there was no satisfactory physical explanation of the variations: they could only be forecasted for a region to which the cyclone was moving, when their existence was indicated in the actual reports from the region where the cyclone was then situated.

The manner in which the barometer changed was always recognized to be of importance, but it was not until the introduction of relatively cheap self-recording aneroid barometers (barographs) that the significance of these changes was more fully appreciated. The first great step forward in modern forecasting since 1885 came in 1908 with the introduction into the reports from observing stations of a precise indication of the character and rate of change of the barometer. From that time the forecaster knew, not merely if the barometer was rising or falling, but also the rate at which it was rising or falling; he also knew the character of the curve of variation for the preceding three hours; he knew, for example, if the barometer had been steady and had commenced to fall, or if it had been falling continuously, or if it had been falling and had commenced to rise.

This information facilitated considerably the task of estimating the travel of weather, but it contributed also to the solution of problem (*b*) and made the prevision of the development of secondaries

more certain; or, what is, perhaps, a more important point, it enabled longer warning of these developments to be given. Still it was mainly from the point of view of the "travel" of weather that this and other improvements were effected and only a little light was thrown on development.

Significance of Cloud Movements

Another advance was made about the same time when it was proved that the direction and speed of the wind at heights between about two thousand feet and five thousand feet could be found very simply from the charts of isobars with practically the same degree of accuracy as that reached by wind-measuring instruments. It had been proved that if the motion of the air were "steady" this would be the case; but it was not until the present writer verified in 1907 the agreement of the hypothetical values with actual records at heights of one thousand five hundred feet and three thousand feet, that it was imagined that the motion could be steady enough for the calculation to be of practical value.

This result has applications in the whole field of practical meteorology. Its bearing on forecasting may be seen by considering that clouds travel and are most important features of weather, and that a means of knowing the direction and speed of the air at heights comparable with those of clouds permits of greater precision in regard to the time at which weather changes will arrive at a place.

A further step forward was made when observations of temperature at different altitudes came to be available in time for use by the forecaster. Such observations are essential to a proper understanding of the general meteorological situation; they are especially valuable in connection with the problem of "development" (*b*). Their usefulness in two special directions may be illustrated as follows:

(*a*) The temperature of the upper air practically sets an effective limit to the maximum temperature which can be reached at the ground in the daytime. If, for example, the temperature at five thousand feet is 25° F., then the temperature at the surface can not rise above 55° F., as a result of a day's sunshine; and if the air is damp as well as cold, the temperature at the surface will not rise above 45° F.

(*b*) A high temperature in the upper air limits the development of vertical motion and the consequent production of cloud. If, for example, the temperature at ten thousand feet is 50° F., and decreases only slowly at higher levels, then there can be no development of cloud above the ten thousand feet level unless the surface

temperature rises above 85° F.; if the temperature at five thousand feet is also 50° F., then the surface temperature can not rise above 80° F., and it is impossible to get the thick cumulo-nimbus clouds of thundery weather without the influx of entirely different air.

One of the most recent developments, a contribution from France, is essentially an extension of the principles enunciated by Abercromby. The atmosphere, at least in temperate latitudes, may be divided into regions of cloudless weather and regions of cloud. A region of cloud consists of a central core of thick cloud and wet weather; in passing from the core to the fine weather area, the cloud experienced depends upon the direction in which the transition is made.

In front of the "core," on the outer edge of the cloud region, are cirrus clouds (mare's tails); nearer the "core" these are replaced by cirro-stratus or a veil of whitish cloud covering the whole of the sky; just in front of the rain area is alto-stratus or a thick veil of grey cloud. On either side of the "core" are cirrus and cirro-cumulus (mackerel sky) or alto-cumulus. Behind the "core" are again occasionally cirrus clouds, but generally alto-cumulus and cumulo-nimbus (thunder cloud), giving showers or thunder-showers

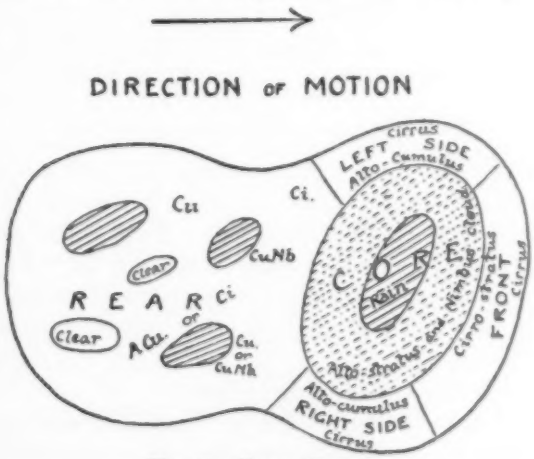


FIG. 1. CLOUD REGIONS

and bright intervals. The diagram, Fig. 1, is a rough illustration of a cloud region as conceived in the French system. Actually there are, in individual cases, many divergences from this generalized representation.

The "core" is the dominating feature and, once it has been identified and its limits observed, forecasting becomes a simple matter, if, as the French believe, the motion of the "core" is not attended with the uncertainty of the motion of the center of a depression, but is practically identical with the speed and direction of the

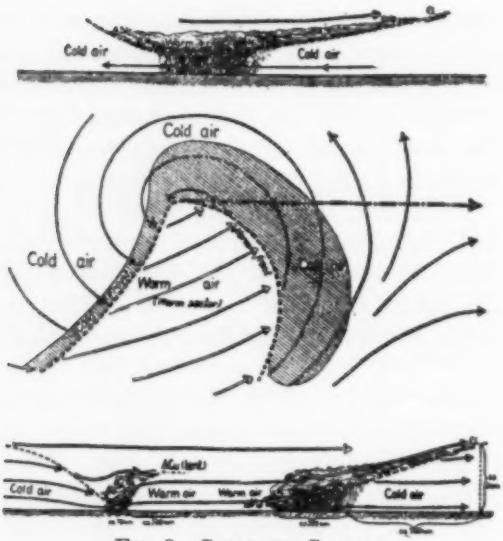


FIG. 2. IDEALIZED CYCLONE

wind at about ten thousand feet. The "core" may be associated with a cyclonic depression, but it may also arise wherever there is a tendency for the formation of a secondary—*i.e.*, wherever there is an area over which the change of the barometer relative to the change in surrounding regions is generally downwards.

THE THEORY OF THE POLAR FRONT

Undoubtedly the greatest recent advance is that associated with the name of V. Bjerknes. Like a poet, he has turned to shape the ideas, latent in the minds of forecasters and physicists, or suggested tentatively, as in Sir Napier Shaw's diagram of the constituent parts of a cyclone, in which he shows a cold east current, a cool or cold west current, and a warm south current, as making up a cyclone.

Bjerknes' theory is briefly as follows:

The polar regions are covered by a mass of cold air, and the tropical regions by a mass of warm air. There is not a continuous change from the cold air to the warm air, but the two masses are separated by a surface of discontinuity—the *polar front*. Cyclones develop at this surface of discontinuity and constitute the mechanism by which interchange takes place between the cold air and the warm air. Each cyclone consists of two sectors, a warm sector of tropical air and a cold sector of polar air. The warm air pushes the cold air in front of it, and at the same time rises over the cold air; the cold air behind the warm sector pushes underneath the warm air, so that normally the warm sector is being reduced in area and is lifted upwards.

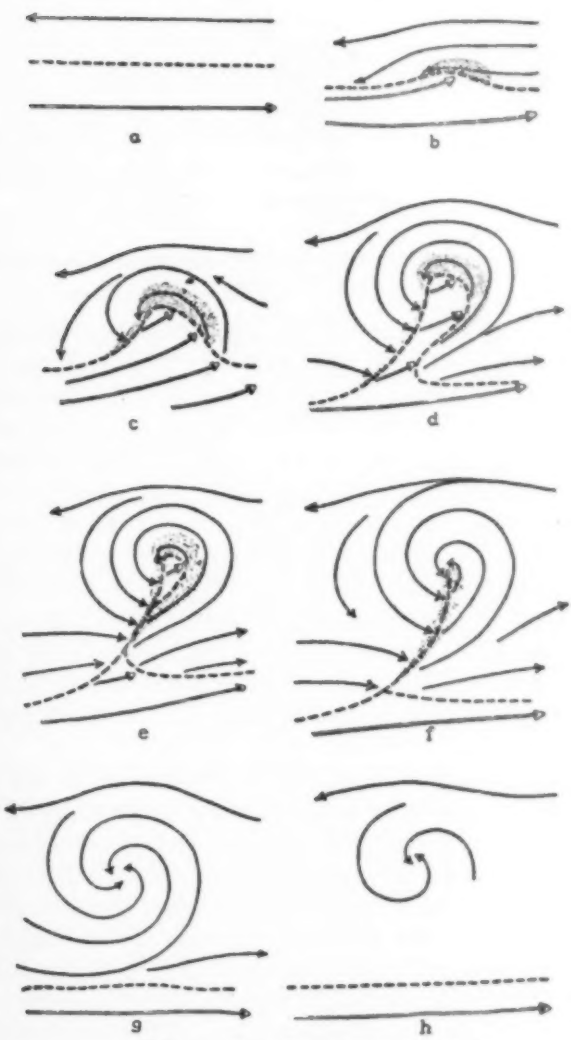


FIG. 3. LIFE CYCLE OF A CYCLONE

In the inner area of a cyclone, the cold air may, and often does, get right round, with the result that the warm sector is cut in two. The cyclone itself then begins to diminish in intensity. The result is a transposition of the polar front and a new cyclone or secondary usually forms with the remainder of the warm sector and the transposed polar air as its constituents.

The diagram, Fig. 2,[1] illustrates the structure of a cyclone. The shaded part is the area of rain (or snow), and the sections at the

[1] Figs. 2, 3 and 4 are reproduced from a paper by J. Bjerknes and H. Solberg, entitled "Life cycle of cyclones and the polar front theory of atmospheric circulation."

FIG. 4. FORMATION OF A SECONDARY CYCLONE SIMULTANEOUSLY WITH THE SECLUSION OF THE "MOTHER CYCLONE"

top and bottom of the diagram are vertical sections through the cyclone to the left and right, respectively, of the path at the center.

The normal birth, life and death of a cyclone are illustrated in Fig. 3. It shows a cold easterly current and a warm westerly current in juxtaposition. The cold air begins to bulge southwards, and the warm air northwards in (*b*). In (*c*) a cyclone has formed, and (*d*), (*e*), (*f*) show successive stages, until the whole of the warm air has been lifted above the cold air. The cyclone gradually dissipates, as indicated in (*g*) and (*h*).

In Fig. 4 the formation of a secondary is shown. The cold air in front of the line of discontinuity can not move away quickly enough; it gets dammed up, and some of it begins to flow backwards and so produces the conditions requisite for the development of cyclones.

In its broad features the theory of Bjerknes is in accordance with the facts of observation and the laws of physics. Further investigations of the upper air will elucidate some points of difficulty and will possibly necessitate modification in details. The outstanding advantage of the theory is the light which it throws on "development." By its aid the forecaster can now see how an existing cyclone will develop; whether it will go on increasing in intensity, or if it will become stationary and fill up; he can also see where a new cyclone is likely to develop *before any actual development has commenced.* Our knowledge of process (*b*), development of weather, is now nearly, if not quite, as good as our knowledge of process (*a*), the travel of weather. Bjerknes has acknowledged his debt to previous investigators, notably Margules and Sir Napier Shaw; but the glory of the architect's work is increased rather than diminished by the excellence of the bricks which others had made ready for the building.

PROSPERITY AND POWER

By Professor **SUMNER B. ELY** and Professor **WALTER F. RITTMAN**

CARNEGIE INSTITUTE OF TECHNOLOGY AND CONSULTING ENGINEERS TO THE PENNSYLVANIA GIANT POWER SURVEY

THERE have been several articles written in the last few years giving estimates of the future growth of the population of the United States—what the saturation point is and how long it will take to reach it. These articles have generally assumed that various checks will hinder this growth. In most cases the food supply has been taken as the only limiting factor; but none of them seemed to consider that our industrial prosperity depends on power generated in the community and that this phase of the question must not be neglected.

Of course, if we are to consider that the United States is in the same class as China or India, then perhaps the doctrine of Malthus can be applied and everything put on the basis of food supply; and it is conceivable that some time in the future the population of the United States might have deteriorated to such a condition. But long before this is likely to happen the industrial prosperity of the United States would have gone, and so it is of great interest to know how long the industrialism of the United States can last.

There seems to be a prevalent idea in the minds of many persons that the great wealth of the United States is due to its farms; and the statement is often made that when we have bumper crops we have boom years. It is interesting to note the United States Census figures given in Table I, which indicate that the manufactures are several times the value of the farm products. The years 1919 and 1921 have been chosen for illustration, because, while there is considerable difference in the figures for the two years, yet they show the proportion between farm products and manufactures to vary but little. We are not concerned with intrinsic value and

TABLE I. VALUE OF THE FARM AND MANUFACTURED PRODUCTS OF THE UNITED STATES FOR THE YEARS 1919 AND 1921

Farm Products	1919	1921
Value of crops produced	$15,400,000,000	$6,930,000,000
Value of live stock products	8,360,000,000	5,468,000,000
	$23,760,000,000	$12,398,000,000
Manufactures		
Finished value	$62,418,000,000	$43,790,000,000

there may be some difference of opinion as to the exact interpretation to be put on these figures; but they show beyond a doubt that our material prosperity is dependent in large measure on our manufactures. Our manufactures in turn are dependent on our ability to generate power, and if the United States is to go on increasing in population and at the same time maintain its prosperity, then power must increase and develop with the population.

The Giant Power Survey definitely indicated the trend of development in manufacture to-day. For the production of power both fuel and water are necessary. In the past each manufacturing establishment generated its own power within its own walls; and if this is to continue, as the country becomes more and more settled, it will involve an increase in railroad facilities for handling fuel; but what is much more important it would be but a comparatively short time until all the available water sites were occupied. A location at a coal mine mouth is less important than the water site, because fuel can be brought to a plant. In other words, water seems to be the limiting factor rather than fuel.

Fortunately the solution for these difficulties is at hand, now that the electric wire has displaced the belt. Power is now transmitted to almost any distance and the manufacturer can locate his plant independently of power-generating conditions. The possible size of the central electric generating power plant, located strategically as to coal and water supply, is nearly unlimited; and it can sell power to the manufacturer cheaper than he can generate it. Fig. 1 shows how purchased electric power is displacing individual

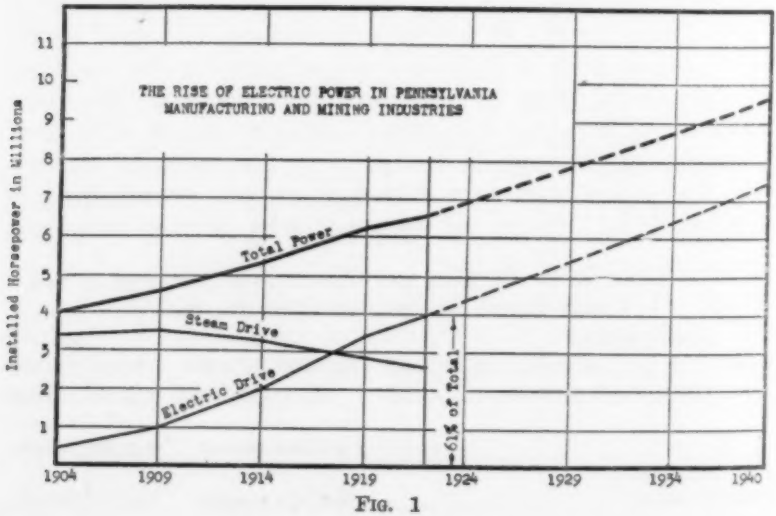


FIG. 1

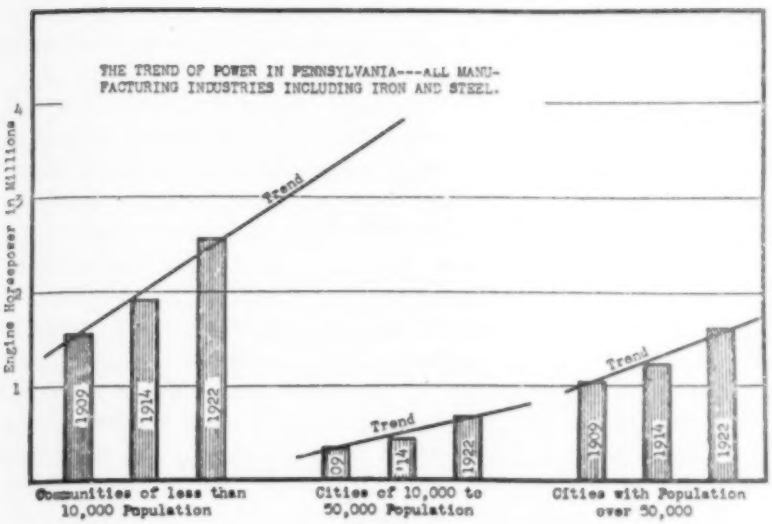


FIG. 2

power generation in the industries of Pennsylvania. In other words, power in manufacturing is becoming as much of a commodity to buy and sell as raw material.

Fig. 2, reproduced from the Giant Power Survey Report, shows that manufactures are already moving away from congested centers. This chart was made by dividing the cities of Pennsylvania into three groups and plotting, first, the sum of all the manufacturing power in cities having over 50,000 population; second, the sum of the manufacturing power in all cities from 10,000 to 50,000 population; and, third, the manufacturing power in small towns and areas outside corporate limits.

It will be noticed how much steeper the line for the communities of less than 10,000 population is. These facts afford a striking illustration of how much faster the power consumption is increasing in small communities, as contrasted with the big city. A map of the state of Pennsylvania, having plotted on it the density of industrial power in each county, will show large areas in the central portion of the state where there is little or no manufacturing. Now, however, that power from large interconnected electric stations is becoming available, these areas are beginning to develop industries; and it is thus possible for the number of Pennsylvania's manufacturing plants to increase to a tremendous extent.

Therefore, as the installations of power stations increase throughout the United States, the country will tend to become a network of wires; and should this happen, industrial plants and

manufactures could increase almost without limit. It becomes, then, a very interesting question as to where all this power could come from and how long it could be maintained.

The first power that man used was undoubtedly his own strength. It has been estimated that the average man is capable of doing 3,500 foot pounds of work per minute and that he can maintain this rate of work for eight hours. On this basis it would take the enormous number of 2,274,000 men to do the same work as one of our 60,000 kilowatt steam turbine units running continuously. When we think of the small space that this machine occupies, the absurdity of operating an industrial community on man power is evident; to say nothing of the many other objections.

The same is true of animal power. A picture has come down to us from the middle ages that shows a prodigious number of men and horses gathered together in a large field to perform some such work as raising a large monolith. To make these men and animals work effectively together must have been a very difficult undertaking. Contrast this with the Liberty motor built during the war for aeroplane service. This motor is rated at 400 horse-power and occupies about the same space as one horse. Its work output is under the most perfect control.

Wave power, tide power, wind power and sun power can all be put in the same class. They have all been tried and all proved unsuccessful. The chief reason is that the power is too diffuse. It would take an enormous platform riding on the waves to generate even a small horse-power. Large greenhouse-like structures have been built to gather the sun's rays; but the power obtained was very small for the very large outlay. Parabolic mirrors have been placed around a boiler, but have been unable to raise steam, much if any, above atmospheric pressure. It is true that by the use of proper condensing apparatus some power could be obtained; but to develop, by this means, the enormous horse-powers needed to-day is out of the question. Since the days of Archimedes various devices have been tried to utilize these forms of energy, but they are totally inadequate and far too uncertain for industrial purposes.

Late investigation seems to indicate that volcanoes, hot springs, etc., are local, and that the internal heat of the earth may be a myth. If it exists, perhaps some day we can tap it; but at present we must realize that water-falls and fuel are our only two real sources of power. The greatest part of the sun's energy coming to the earth is consumed in heating the atmosphere and in evaporating water. A small part of this is recovered from the rain of clouds falling on high ground and the energy of flowing water results; and

hence our water power. That portion of the sun's energy that goes into vegetation has some power possibilities, for wood and other vegetable matter make good fuel. Our wood supply, however, is being used up some five times faster than it is being replenished by new growths. Possibly certain plants might be grown each year from which oil can be extracted which could be used as fuel. However, our real source of supply is that portion of the sun's energy that went into vegetation in ages past and is now locked up in the form of coal.

Let us consider the water power possibilities first. The United States Geological Survey estimates that the potential water power resources of the United States are about 55,000,000 horse-power, available 50 per cent. of the time; of this only about one fifth has so far been developed. From these figures, if the water power were all developed, it would produce 242 billion horse-power hours per year.

The actual requirements of the country are given in Table II for the year 1922. The industrial figures of the table were obtained by applying the known load factor of Pennsylvania to the installed horse-power of the United States. The railroad horse-power hours

TABLE II. THE HORSE-POWER HOURS DEVELOPED IN THE UNITED STATES IN 1922

Manufacturing and mining, including electric power purchased	86	billion	horse-power	hours
Electric power stations, excluding that sold to industry	20	"	"	"
Railroads	45	"	"	"
Automobiles	27	"	"	"
Navigation and miscellaneous	80	"	"	"
Total	258	"	"	"

have been estimated from a knowledge of the coal used by the railroads in 1922, and the automobile figure from the gasoline consumption. The navigation and miscellaneous figure is based partly on registered tonnage; but it is rather loose, for it is difficult to say what proportion of our ships' fuel should be charged to the United States. However, the figure seems to check out from other points of view, and it is close enough for our purpose.

Comparing now the two final figures, it will be seen that with all our water power developed, it would hardly have met the demand in 1922. If now Fig. 3 is looked at it will be seen that if our industries maintain their present rate of growth, they will have doubled by 1950. Our power requirements would seem to be doubling every

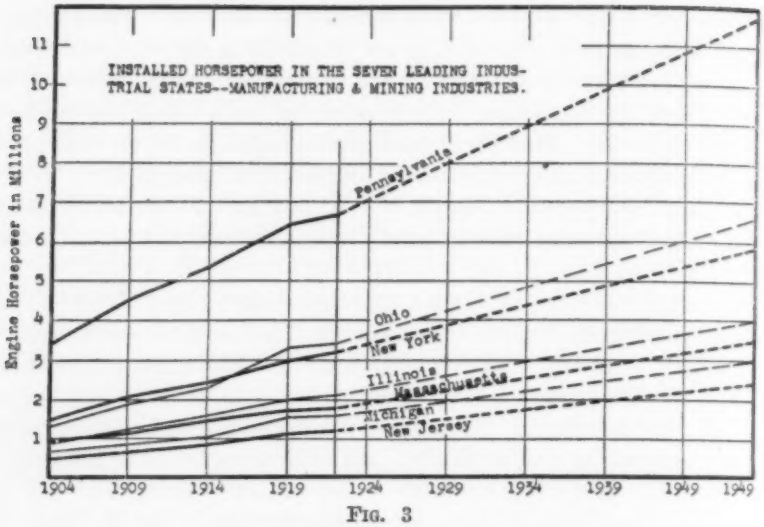


FIG. 3

twenty-five years. How long this will keep up is only conjecture; but the fact that the electric power industry itself is doubling every five years, and that Giant Power and Superpower are becoming facts, would lead one to believe that if the other necessary factors develop at the same time, we may be entering an era of development that will be greater than anything ever yet known.

However this may be, it seems certain that although water power may carry some of our load, our real dependence must be placed on our fuel reserves. And fuel reserves mean coal reserves. Natural gas is practically exhausted. Our oil can not last much longer, and this will probably make a further demand on the coal, as our gasoline of the future is likely to come from coal distillation earlier than from shales. Furthermore, while we have been considering coal from a power generation point of view only, in reality a large portion of the coal mined is used for industrial heating and other processes; so from every standpoint it becomes of increasing interest to know how long our coal reserves are likely to last.

In the state of Pennsylvania we know with considerable accuracy how much coal is still in the ground. The whole state has been carefully mapped and measured by the State Bureau of Topographic and Geological Survey. Table III contains their bituminous coal figures. Anthracite coal deposits we have not considered; they are comparatively small and used mostly for domestic purposes. The figures given in Table III for the original deposits include all veins, whether minable or not, while in the estimate of recoverable coal only veins that are thicker than 18 inches are in-

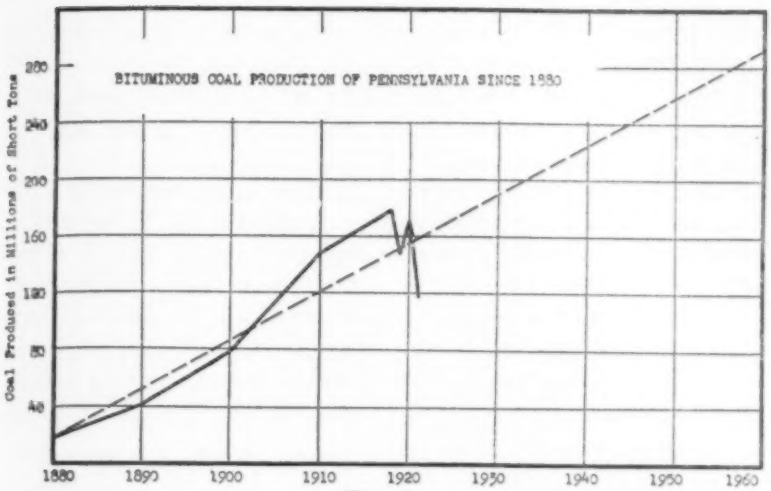


FIG. 4

TABLE III. THE BITUMINOUS COAL OF PENNSYLVANIA

Original Deposits	Mined Out	Recoverable
75,259,055,000	5,519,665,000	43,830,860,000

All figures are in short tons

cluded, which accounts for the difference very largely in the size of these two figures. There is no lignite or sub-bituminous coal in Pennsylvania and all the 43 billion tons of reserve are good usable coal.

Fig. 4 is a plot of the bituminous coal mined in Pennsylvania since 1880. Assuming that the increase of coal mined in the past, as shown by the curve, will be continued, the dotted line has been projected into the future. Equating the area under this line to the 43 billion tons coal reserves, it will be found that these reserves will be exhausted in 118 years. If, instead of considering a yearly increase, the assumption is made that the coal mined each year will be the same from now on, then it will be found that the 43 billion tons will last about 250 years. The true figure probably lies somewhere between these two extremes. This means that the end of Pennsylvania's coal is in sight.

This same method can be applied to the coal resources of the United States, but with very much less accuracy. In 1913 an International Geological Congress was held in Canada, the result of which was the publication of three volumes giving the estimated coal reserves of the world. This was a wonderful piece of work and the records are of the greatest value, but the same degree of accuracy can not be expected, as in the Pennsylvania estimate where each square foot of ground was laid out on a drafting board and

planimetered. The coal in our western states is by no means as well known as that of Pennsylvania. Then, too, the figures given for recoverable coal include all seams down to 12 inches thick, while the Pennsylvania figures do not include anything less than 18 inches thick.

For these and other reasons the method of calculation used for Pennsylvania is not satisfactory when applied to the United States. Such figures as we find, however, lead to the belief that in a very few hundred years all our best coal will have been exhausted; the zenith of industrial prosperity will have been reached and from then on a gradual slowing down of production will take place.

In Table IV is given the distribution of the world's coal reserves as determined by the Geological Congress. As North America has

TABLE IV. DISTRIBUTION OF THE WORLD'S COAL RESERVES

North America	68.7 per cent.
Asia	17.3 " "
Europe	10.5 " "
Australia	2.3 " "
Africa	.8 " "
South America	.4 " "
	100.0 " "

nearly 70 per cent. of the coal of the world, it must be looked to very largely to keep the world going and what has been said about the United States can probably be said about the world generally.

Whatever interpretation we choose to put on such figures, we certainly must realize the rate at which our resources are going. For countless ages man has lived on this earth with the coal practically untouched, then suddenly, less than a hundred and fifty years ago, the industrial age began, with the invention of machine tools and the steam engine, and in that short period this enormous consumption of coal has taken place. Our fuel-saving refinements will help, but they seem like a drop in the bucket in the face of the ever-increasing demand. As Fred R. Low, president of the American Society of Mechanical Engineers, has well said: "It is a good thing for us that the industrial age did not start in the time of Tutankhamen, or to-day we would be fighting among ourselves for the last few remaining heat units." And even if we care nothing about the future from an altruistic point of view and ask ourselves the question: "What has posterity ever done for us?" still it is interesting to wonder if 2,500 years from now the words "prosperity" and "civilization" will have taken on a very different meaning.

Our present outlook is that when the coal goes so will prosperity. Will science do anything for us before this happens? Will somebody some day discover how to make heat run up hill, so that we will need a new theory of thermodynamics; or will some one get control of the energy we believe to be in the atom? These are dreams. We have been living in a time when we have seen under our very eyes tremendous changes taking place in industrial life. The application of scientific principles has developed rapidly, and we have therefore come to believe that this rapid development will continue, and that sooner or later some source of energy, other than coal, will become available. Our attitude is one of waiting for something to turn up. Possibly a wiser and certainly a more practical attitude would be one of conserving our resources.

Perhaps true prosperity is not industrial prosperity at all, and that man was happier in the olden days. Man got along without power until just yesterday, so to speak, and most of mankind get along without it still. It may be that man is not as happy now as he was, but it surely can be said that wealth and comforts are widely distributed as never before; and whether we believe this industrial age with its great mass production is best for mankind or not, the handwriting on the wall says that it has come to stay and to increase.

Our civilization is one of industrial production, and this is the one difference between our civilization and the many civilizations that have preceded it and failed. Will our civilization endure? If it does, then power must endure.

THE PHYSICAL BASIS OF DISEASE

XI. MEDICINE OF THE FUTURE

By THE RESEARCH WORKER
STANFORD UNIVERSITY

"IT would be interesting to know the relation of theology to medicine a hundred years from now," said the manufacturer, as he wished the research worker and family Godspeed, at the railway station, a few evenings later.

That night the research worker tossed in a stuffy berth, a medley of dreams and half-waking thoughts, essence of a hundred sleepless nights. In his dreams he revisited California in the thirtieth century. Saw the old placer region, now a segregation district for industrial plants. The eugenic colony of the San Joaquin valley. The great state wineries of the Fresno region. The crime-prophylaxis station at Carmel.

"Yes," he murmured, wakened at a junction by returning college students, with their ever-varying parodies on Alexander's Ragtime Band, "it would take a Tamalpais."

Unable again to sleep, he dressed and jotted down his main impressions of Thirtieth Century California.

2

I found myself in the office of a great physician of the thirtieth century.

"My bill?" asked the patient.

"Two and a half wilsons," replied the physician.

"May I see those coins?" I asked.

"Gold and silver mixtures," the physician explained. "Named after Patrick Wilson, first President of the Nordic Union. No relation of the Wilson of your day."

"Nordic Union?"

"Founded, 2113, after the second Pan-Europasiatic War. Hundred fifty million killed. California invaded. Half a million women and children killed here. Here's the atlas. Nordic Union, red. Mediterranean, green. Asiatic, blue. African, buff."

"The value of a wilson?"

"Average daily living expense, one adult, Nordic Union. Relative proportion of gold and silver varied from time to time to stabilize its purchasing power. Size and design constant. Similar

units in other Unions. Mediterranean unit, twenty per cent. less gold. Asiatic, forty per cent."

"A handicap to business," I objected.

"Interunion transactions are mainly by bankers' credit. The four world units are equalized in world-purchasing power by import taxes or bonuses, equal to the difference in the gold content of the units involved. With a normal trade balance, the taxes and bonuses offset each other. Otherwise, world-wide free-trade."

"But the revenue of a country?"

"Mainly from state owned shares in public utilities. No state allowed to own more than 33 1/3 per cent."

3

The physician's office expanded to the dim-lit interior of a great Protestant Church. The choir swung into the familiar refrain. Trumpets dominated the orchestra. The standing congregation raised their right hands:

> **I rejoice! I rejoice! In Divine biologic laws.**
> **I obey! I obey! Thy Divine biocommand.**

Changing to the voice of a great historian in whose study I was sitting.

"The Biologic Reformation," he was saying, "dates from 2015, the Miracle of Mount Tamalpais. Here is the account. Third Testament, Second Chapter, Letters of St. O'Neill, reporter for a San Francisco paper, who won the Pulitzer prize for the best description:

> **5. And, on the third day, a Wondrous Light appeared over Tamalpais, increasing to a Brilliancy no eye could stand, a Light leaving no record on photographic plates.**
>
> **6. And, from this Brilliancy, there materialized a Great Face, Countenance of Eternal Youth, over-topping the stars, visible to far distant Sierras.**
>
> **7. The Lips opened, and, in a Voice each heard in his own tongue:**
>
> **8. "I give unto you a new Command, the Biologic Law. From the anthropomorphic brute in whose body I created you, you have evolved a demi-deity. You have gained much dominion over external forces. WE are pleased. Now, say I unto you, gain you also dominion over your own biologic selves."**
>
> **9. The Face dimmed, slowly disappeared. And those who would approach found Tamalpais denuded of vegetation, with heat so intense none could ascend.**

4

The Bible shrank to a wine glass in the hand of a great industrial chemist.

"Not the rotting fruit and putrefying grain of your generation," he was saying, "but juices of freshly gathered fruits, mixed with other vegetable products. Freed from putrefactive microorganism by porcelain filtration. Aged. Aromatized. Carbonated. Vitaminized and neurhormized by ultraradiation. The inception of the process dates from your time, the early partial vitaminization of inert oils by ultraviolet rays. Wine is at present the largest industry in the state. A million employees."

"The labor?" I asked.

"Agriculture laborers, mainly Italiojapanese hybrids. Technical workers, largely Francoprussian blends."

"Hybrids! Blends!" I exclaimed. "Supervised marriage!"

"No. Public opinion discourages undesirable hybridization. Otherwise, the individual usually marries at puberty the mate of his choice."

"At puberty!"

"To be exact, during the nuptial sabbatical, first pubescent year."

"My own research field," he continued, the wall of the room disappearing, revealing his private laboratory. A topsy-turvy land. Inverted receptacles, up-side-down filters, fragments of broken apparatus floating near the ceiling. "Is aeriometallergy. Gravneutral, gravnegative alloys."

"Gravnegative physics," he explained, "dates from 2516, the discovery of differences in the gram-momenta of certain metals moving in vacuo. The first gravneutral subelectron was not isolated till nearly a hundred years later, however. The first gravnegative subatomocentrosome, not till two hundred years later. Our main commercial supply of negons is from subcentrosomal cracking."

"The chemistry of my day?" I asked.

"Ten centuries of the pseudo-chemistry scrapped, by the beginning of the modern era. This we date from 2781, the perfection of methods for electron and centrosome synthesis."

5

The chemist's voice changed to the natal wail of an infant in the hands of an obstetrician.

"Nordichebraic hybrid," he was saying. "Superior to the Nordicarabic and Nordicegyptian blends encouraged in England."

The resident hormonologist took up a hypodermic syringe.

"You had hormones in your day?" he asked.

"Insulin," I said.

"Crude initial product. Mixture," he replied. "This is gonstasin. Highly specific antimitosigen. Act solely on the attraction-sphere centrosomes of gonocytes. Enough bound to the centrosomes to delay gonocyte mitosis ten to fifteen years. Delays puberty. Females, till twenty-fifth year. Males, till thirtieth. Offset by postponed menopause and delayed senimpotence. Same length of time."

"The purpose?" I asked.

"Our natural reproductive period was well adapted to prehistoric man. Poorly adapted, however, to modern education, to modern life-expectation. Youth-prolongation is compulsory in the Nordic Union. All new-born. One of our most valuable eugenic and hygienic measures."

"Your life-expectation?" I asked.

"Increased rapidly during the first five decades after Tamalpais, with the resulting general application of known hygienic facts. Since then, advance has been slow, depending mainly upon laborious mastery of new facts. Our average life-expectation today is 67.4 years. Eventually, we hope to reach the three-score-and-ten of Biocommand."

"Not my understanding of the text," I objected.

"Careful retranslations, during the time of His Holiness Tamalpais I, show that this was the original meaning."

"The Chief has his neghenry on the roof," he added, "going to show you the senilorium."

6

"Looks familiar," I said, as I found myself seated in the well-known model.

"Yes," replied the hormonologist, "we've reproduced the external features of the historic car preserved in the Memorial Museum, at Henfrd. The surface henry and neghenry are the official Nordic Union insignia for physicians of the ford class. Perpetual tribute to that far-seeing man, who contributed a quarter of his fortune to founding the Research Institute for Molecular Physics, at Ann Arbor, from which came the discovery of rectangular ultra-radiation-interference in radio-active crystals, basis of modern diagnosis."

The henry rose to the passenger level.

"Physician of the ford class?" I asked.

"On graduation, medical students are licensed as B-class physicians, entitling them to practice only under the supervision of a physician of higher rank. After five years, about two thirds of them are raised to the A-class, allowing independent practice. Ten

years later, about a quarter of the A's are raised to the consulting, or ford class, M.FD. Corresponding to the highest rank in other professions, Ph.FD., D.FD., etc. The fordate is required for responsible public health and teaching positions. Most research workers are fords, though some of the best work ———

"Oyez!! Oyez!! Oyez!" from an approaching air-liner.

"Emergency-ambulance call," said the hormonologist. "Grab th' straps!"

And the henry shot forward to the ground.

7

We reached the ground a few seconds before the slowly descending body. Its fall retarded, I was told later, by a gravnegative suit.

The body landed on its feet. ("God! It's Ford Jones!") Slowly collapsed to the ground. Fragments of viscera rained down from the slowing propeller, now overhead, a three-foot length of intestine sliding from a frond of an adjacent palm.

A hemostat plunged into the gaping abdomen. Jugular exposed. Thermos trocar inserted.

"Control the flow! Thirty cc per second."

Ruptured spleen, shreaded stomach, intestinal fragments, thrown to the ground. A dozen rapid hemostats. And the emergency-ambulance dived to the ground. Another thermos. And, disregarding all traffic regulations, the burdened ambulance sirened toward the hospital.

"Spectacular stunt!" I said. "But what was the use?"

"Oh! He'll be all right. Few weeks."

"Exsanguinated!" I objected. "Practically eviscerated! Stomach, intestines, spleen all gone."

"Liver and kidneys intact," he replied. "What more d'you want? Didn't you have intravenous feeding in your day?"

"Come to think of it," I said, "some one was trying out intravenous glucose injections. But the shock?"

"The thermos fluid was your old friend, Locke's solution. Plus the usual intravenous anesthetics. To this we have merely added α –, β – and γ – anti-shock hormone, a synthetic colloidal oxygen-carrier, synthetic prothrombin and streptosalvarsan. They'll probably drain him out in the hospital. Fill him from pooled donors. I believe his blood formula is $A_2C_1\delta\gamma$. On record. Subject to call."

"But lack of asepsis?" I insisted.

"Continuous lavage. Modern variant. Your Dakin's solution. The main thing to fear is the λ-group streptococcus. But here we are."

And the henry slanted to the ground.

8

He shifted to surface transmission. We glided along a flower-bordered driveway.

"How about organ transplantation?" I asked. "One of our prophecies."

"Transplantation of certain simple tissues is part of ordinary hospital routine. Done, however, only after painstaking blood-grouping and quantitative horm-determinations. Organ transplantation, however, involves such prolonged delicate technic that it is rarely attempted, except in research."

The henry entered a park. Attractive bungalows. Venerable patients. One ancient, squatted in buddhistic pose on a rock, an electric light suspended a few inches above his head.

"Interesting case," commented the hormonologist. "Shaves and anoints his head daily. Sits for hours under his electric light. Perfectly happy. Picturing himself the second Tamalpais. We've merely substituted electricity for his original 'sacred lamp'."

We passed through the senile colony to an imposing group of buildings in the rear.

"Desenilization hospitals," he said.

"Desenilization," he explained later, "had its inception in the 2313 Los Angeles epidemic, following the introduction of a group of natives from Tibet. The epidemic was characterized by a rapid shrinking and jellification of the body. Particularly marked in the bones. Before death, the patient was often reduced to half his initial height."

"Sounds like some of our war infections," I said.

"The disease was transferred to rodents," he continued, "and was propagated in rats, for nearly two hundred years, before the causative agent was isolated and cultivated. From pure cultures of this microorganism a series of highly specific hystolysins were finally isolated. One of these is almost absolutely specific for degenerated cells, particularly of the connective tissue groups."

"Desenilization," he added, "is usually attempted between the sixtieth and sixty-fifth year. There are two stages. First, a gradual, careful desclerosation of the body, by daily, intravenous injections of hystolysin. Followed by a forced multiplication of residual normal cells by prolonged cross-circulation with a rapidly-growing youth.

"The process usually takes about a year. Is attempted only in carefully selected cases. Early attempts with advanced arterio-sclerotic types gave disastrous results. At the end of the process the individual is restored to about two thirds his original height.

Has about a third his original muscular strength. But usually has distinctly, often markedly restored special senses and mental vigor."

"The average duration of mental vigor," he continued, "is increased about fifteen years by the process. The average life-expectation, about five years."

"How often can the process be repeated?" I asked.

"Repeating the process five to fifteen years later produces such slight improvement in mental condition that it is no longer attempted."

"Desenilization is open to all," he explained, as we drove back toward the entrance. "It is, of course, expensive. But special provision is made for the free desenilization of individuals of outstanding mental attainments. The present much-beloved President of the Nordic Union, for example, was desenilized in this hospital, free of charge, about seven years ago."

(To be continued)

THE CONTENT OF SYSTEMATIC BIOLOGY

By Professor G. F. FERRIS

STANFORD UNIVERSITY, CALIFORNIA

THOSE who are confronted merely with the printed title of this paper will doubtless be justified in wondering which of the two possible pronunciations and consequently which of the two possible meanings of its second word it is my intention to employ. This apparent ambiguity is intentional, for I am really concerned with both. It is my hope that by a discussion of what I conceive to be the con′tent of systematic biology I may in some degree disturb the content′ of systematic biologists.

One whose biological interests happen to center chiefly about the problems with which the systematist is concerned can scarcely have failed to observe that systematic biology is somewhat in disrepute. Or at least if he has not himself detected it he will have had it impressed upon him by others who profess to have done so. In fact, the observation is one that it seems none but the most unobserving can avoid. There are certain national scientific societies of an honorary character to which no one can gain admission on the basis of systematic work alone, although scientists whose qualifications are chiefly literary and journalistic may be admitted into the circle of the elect. There are universities that will not grant the doctor's degree as a reward for systematic work, although they will grant it for other work that to the doubtless prejudiced eyes of a systematist appears to be of no very great significance.

And so, with the frequent repetition of this observation—a sort of reverse Couéism, as it were—the systematist, if he be not either strong-minded or supremely indifferent, may come to be somewhat depressed by it. He may finally conclude that his own field has but poor pickings and turn a longing gaze toward those other and still verdant pastures where for the moment there disport the dainty Drosophilas or where parades the proud pH. Worse than this is the fact that the younger men, casting about for their particularly fitting niche in the scheme of biology, are not likely to look with any marked favor upon attaching their roots in such a sterile field.

Now, what can the systematist do about all this? Of course the simplest thing that he can do is to give up being a systematist. He may grow a few flies or a few silkworms or perhaps a few flowers or whatever else is convenient, find out what a chromosome is and what "crossing over" and "linkage" mean and call himself a

geneticist. He can go out into the fields and engage in any one of several delightful and harmless activities that will permit him to intrude within the society of the ecologists. Or he may elect any one of several other more or less similar means of escape that will readily suggest themselves to one who desires above all to swim with the current.

But if he refuses to forswear his faith and elects to remain a systematist, if he is able by some such arguments as I have elsewhere presented to revivify his belief in the worthwhileness of his activities, what is there that he can do to aid in the elevating of his work in the estimation of other biologists—or as some might maliciously prefer to put it, of biologists? We are of course all familiar with the copy-book maxim that it is not what people think of you but what you are that really counts, yet after all there is a certain amount of satisfaction in being appreciated.

In the first place, what is the common conception of a systematist? As I have gathered it, it may range among those who are not themselves systematists from a belief that he is an encumbrance upon the earth to a grudging admission that such work must be done by some one. The latter is usually accompanied by a query as to why any one should want to do it. Some regard the systematist as a mere cataloguer. Others, disturbed by certain of his incidental activities, look upon him as a juggler of names. To some he is merely a man who describes new genera and species without end in order that he may delight in seeing his name printed after them in accordance with the quaint custom of his tribe. Some would unkindly remark that he is merely a pseudo-scientist, and I suppose that some day we shall have to debate the question as to what science really is.

What do systematists think of themselves and of the purposes and limitations of their work? After all, this is the more important. It is with their conceptions that I am the more ready to quarrel. We may cheerfully excuse those who from lack of acquaintance with our work do not understand or appreciate it. We can hardly be so lenient with those who do not understand or appreciate the possibilities of their own work. Here, it seems to me, is the real root of the difficulty. The systematists themselves—of whom I consider myself to be one—are to a great degree responsible for the present situation. They do not come into the court with clean hands.

I may perhaps misinterpret the views of systematists, yet my conclusions are drawn from their work. Apparently there are many who are indeed content with the mere recording and superficial describing of supposedly new species, to whom the title, "One hundred

species of something-or-other new to science," represents the very apex of achievement and this in spite of the fact that we already know far more species than we know what to do with. Apparently there are some who conceive their work as chiefly nomenclatorial and who regard systematic biology as synonymous with a system of names. Apparently the majority are content if they have described the more obvious external features of an organism and on this basis have made some attempt to allocate it in the system of classification.

These systematists are indeed working in a field that is destined to sterility. It is a field about which there exists a barrier through which the refreshing streams of thought from other fields may not penetrate. These systematists have drawn or have permitted to be drawn a rigid distinction between their own work and that of the geneticist, the physiologist, the chemist and the experimental biologist.

It is against this isolation that I would protest. Rather than to permit genetics or physiology or biochemistry to push systematic biology into the humble seat in the ashes where it shall sit for all future time as the Cinderella of biology I would urge that systematic biology reach out and appropriate unto itself the fine raiment of these sisters. After all, none of these things is an end in itself. They are all rather methods that can be applied to various ends. They can be utilized by the systematist.

There are really two things that the systematist is after. One of these is the purely practical aim of making it possible to identify species. Along with this, of necessity, goes the entire matter of naming and arranging species in some sort of order so that we may be able to talk about them. This aim can be attained after a fashion without much consideration of other factors and in many cases by means of the most artificial of characters and with a minimum of actual knowledge. Any one, for example, can tell a horse from a cow at a glance without being able to give any definite analysis of his reasons for separating the two and without being able to tell any one else how to distinguish between them. However, this describing and naming of species is an entirely legitimate and in fact a necessary aim. The unfortunate thing is that it is so often considered as constituting the whole of systematic biology or taxonomy and that even where it is the sole aim of the systematist that aim is so widely missed. In actual practice it constitutes a very large preponderance of the routine work of the systematist, even of the systematist who would avoid all routine if it were possible to do so.

Nevertheless, in addition to this mere identifying and naming of species there is still something else. This identifying and nam-

ing is merely knowledge without understanding. It is one thing to discriminate among species after we know them to be distinct, it is another to find valid reasons for our discrimination and to understand the relation of species to each other. Knowledge without understanding is perhaps not valueless—it is sometimes extremely dangerous—but it at least is an inefficient and a poor thing. Its consequences in systematic biology may be seen in the activities of a botanist who named two hundred species of a familiar western flower because of his religious conviction that species are immutable things, fixed since the creation, and that consequently two forms which are recognizably distinct can not come from the same ancestors! It is the kind of thing that appears all too frequently in systematic work, although probably from far less sincere motives than were those of the botanist.

The attainment of such understanding involves a great many things that need not, and in fact should not, be involved in the purely practical work of identification. For practical reasons the latter should be made as simple as possible. The attainment of the first may not be simple at all. Here the systematist should employ all the tools that are available and that can give him any aid. It is here that the methods of the comparative morphologist or anatomist, of the physiologist, of the geneticist, of the experimental biologist, even of the chemist may be brought into use. It is to include all these things that I would urge the extension of the conception of systematic biology. It is not the method utilized, but the aim that determines what our work is to be called.

Let me illustrate by actual examples.

There is a certain group of western plants that are extremely puzzling to the systematist. Whether there is but one species or whether there are several is a question that can not be answered on the basis of herbarium specimens alone with any degree of satisfaction. However, a botanist has attacked this group by way of the methods of the geneticist and has arrived at certain definite conclusions as to the number and the characteristics and the genetic relationships of the species involved. I can not see that this is any the less systematic work because it has been done in this way rather than in that which the botanical systematist ordinarily follows.

There is what is supposed to be a single species of scale insect which occurs on a wide range of plants, frequently becoming a rather serious pest in orchards. As far as structure is concerned apparently but one species is involved, yet in form and habit individuals from the various host plants present a wide range of difference and there is a very definite question—one that is by no means purely academic—as to what these forms are. One may con-

template the spectral remains of the insects as they appear when ready for study under the microscope indefinitely without any prospect of a solution. This solution of the question probably can be attained, however, by experimental methods involving the careful rearing and transference of specimens from one host to another. This is experimental systematic biology. As a matter of fact, work of this sort is very sadly needed, for there has long been doubt as to the effect upon insects of a change in host. There is very little valid evidence one way or the other, but no inconsiderable amount of the systematic work in certain groups has been definitely influenced by preconceived judgments as to what that effect would be. If the question can be settled by experimental methods the recognition of the species by the ordinary procedure will present no difficulty.

There is a group of scale insects from one species of which our entire supply of shellac is obtained. Altogether, there are about fifty species known in the group. Only a few of these produce a true lac, others produce something like lac, while still others produce a substance that has no resemblance to lac at all. Here there is room for the application of chemistry in the study of these forms. If a chemical study of the secretions of the various forms should reveal that each has a specifically recognizable secretion, would not that justifiably be acceptable as a contribution to systematic work? True, no one would wish to take the trouble to make a chemical analysis of the lac in order to identify a species, for they can be identified more easily by other means, but such chemical study would undoubtedly aid in that understanding of the relationships of the species which we should have for systematic purposes. The bacteriologist, it seems, actually must rely upon chemical reactions as a matter of routine procedure in order to identify the forms with which he deals.

Personally, I am convinced that there are such things as physiological species. After all, what are structural differences but the expression of some preceding physiological activity? If this be true, there must be forms which will differ in their physiology even if not in their structure. It may not be necessary or desirable to recognize these forms by names, but at least a physiological study of them would aid in a proper understanding of their relationship to one another.

I do not wish to be misunderstood as proposing that every systematist should be at once a geneticist, a physiologist, a chemist, a comparative anatomist, an experimental biologist. I do believe, however, that he should be one of these things at least and should

have some appreciation of the others. I do contend that the aim of systematic biology, that of discriminating among those myriads of forms of living organisms that we call species and of understanding their genetic relationships to each other is broad enough and well enough worth while to include under its aegis workers in all these fields.

I do not wish to be misunderstood as proposing that every species shall be subjected to genetical and physiological and chemical as well as structural analysis before it is given a name and described. Obviously nothing of the sort is possible with the millions of forms that occur in the world. There is in general no need of any such elaborate program, and for many years to come we can get along very well in the majority of cases with merely an adequate structural analysis and without being too curious as to the exact genetic status of our species. With the majority of species it is almost enough merely to know that they exist and can be recognized when the occasion arises. But when the occasion does arise and when anything at all is to be gained by the use of these other methods they should be used.

I would then maintain the thesis that if systematic biology will extend its definition of itself, if it will revise its estimate of itself, if it will in addition raise its standards of work, it will automatically deserve and, let us hope, regain the esteem of the workers in other fields.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

SUGAR FROM SUNFLOWERS

A NEW sort of sugar may soon be on the market that is sweeter and better and possibly cheaper than common sugar. I call it "new" because it is unfamiliar and not yet for sale in the shops, but as a matter of fact it forms a large part of our daily food already. The reader, if he be an ordinary person—though no one will admit that he is—is now consuming the new sugar at the rate of a pound a week and gets from it some six per cent. of his muscular energy.

The chemist knows of scores of different kinds of sugars, but the public knows only two, beet sugar and cane sugar, and these two are really one, sucrose, the chemist calls it. When we eat this sugar it is split up into two equal parts, one of which is known as "glucose" and the other as "fructose."

The chemist, who analyzes sugars by passing a ray of polarized light through their solutions, calls the former "dextrose," or the right-handed sugar, because it rotates the ray to the right, and the latter "levulose," or the left-handed sugar, because it rotates the ray to the left.

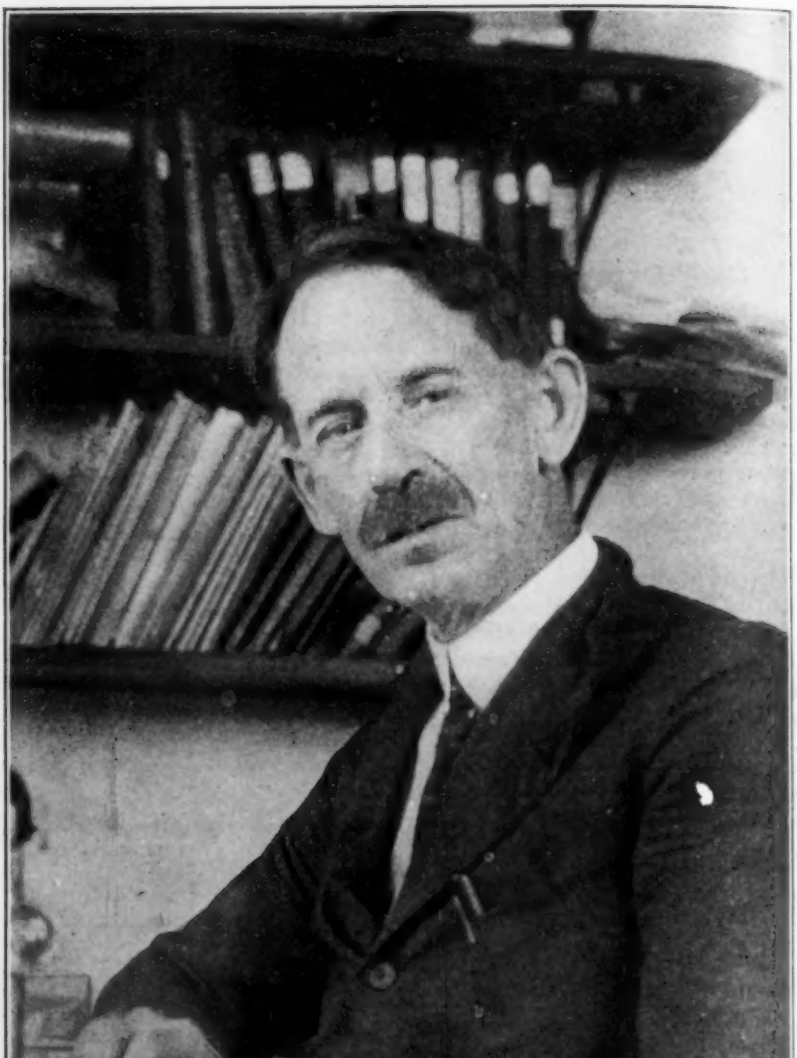
Now glucose or dextrose made from cornstarch has in recent years come into common use as a syrup for making certain kinds of candy, and can now be prepared as a pure white powder. But it can not completely replace cane sugar because it is not nearly so sweet.

The other sugar, fructose or levulose, has a sweeter disposition than either its twin, glucose, or its mother, sucrose. In fact, two pounds of levulose would go as far as three pounds of cane or beet sugar in sweetening food. It is also much more soluble than common sugar and so can make a sweeter syrup. A spoonful taken on the tongue vanishes like snowflakes in the sun.

Levulose gets its other names of fructose or fruit sugar because it occurs commonly in sweet fruits, as it does also in honey. But it has never been prepared in commercial quantities because of the difficulty of purifying it. This difficulty has at last been overcome by the researches of Jackson, Silsbee and Proffitt at the Bureau of Standards, who have worked out a process of producing it by the ton in a pure white, crystalline form. This may make levulose a formidable rival of common sugar, since it may be made from a plant that is tougher, wider spread and more prolific than either beet or cane.

This is the Jerusalem artichoke. The tubers of the artichoke are similar in composition to potatoes but, instead of the starch of potatoes, they contain a similar substance, known to chemists as "inulin." Starch, digested in warm acidified water, turns into the right-handed sugar, dextrose. Inulin, treated in the same way, turns into the left-handed sugar, levulose.

It seems that we can get more sweetness from an acre of soil by growing artichokes than any other crop. The average yield of potatoes in the United States is three tons per acre. In England this is doubled. But fifteen tons per acre of artichokes have been raised in Pennsylvania, using the strain known as the Mammoth White French Jerusalem Artichoke.



PROFESSOR HERBERT SPENCER JENNINGS

Henry Walters professor of zoology and director of the biological laboratory at the Johns Hopkins University, who is the first recipient of the Joseph Leidy Memorial Award of the Academy of Natural Sciences of Philadelphia.

In the midst of the Great War when England seemed in imminent danger of starvation through the cutting off of her shipping by U-boats, the British government set the Royal Society to finding what crop would produce the largest amount of food on this limited land. The War Food Committee reported, in "private and confidential circular No. 46," that the Jerusalem artichoke was better than potatoes, for it could be grown on waste land without preparation and with little cultivation, and that the yield in gardens ran up to 20 or 22 tons per acre.

Unlike the sugar beet, the artichoke is not impaired in sugar content by freezing, so the tubers can be kept in storage or left in the ground until it is convenient to work them up in the factory. The factory can therefore be kept running for eight months in the year instead of three with consequent reduction of overhead and investment.

The tubers yield ten to twelve per cent. of levulose. Formerly crystallized levulose was sold, or rather quoted in the catalogs of rare chemicals, at over a hundred dollars a pound. The new process may reduce the price to that of common sugar, or cheaper considering its superior sweetening power. It has one disadvantage that may interfere with its table use; that is, it absorbs water from moist air more readily than salt, and so is apt to deliquesce into a syrup.

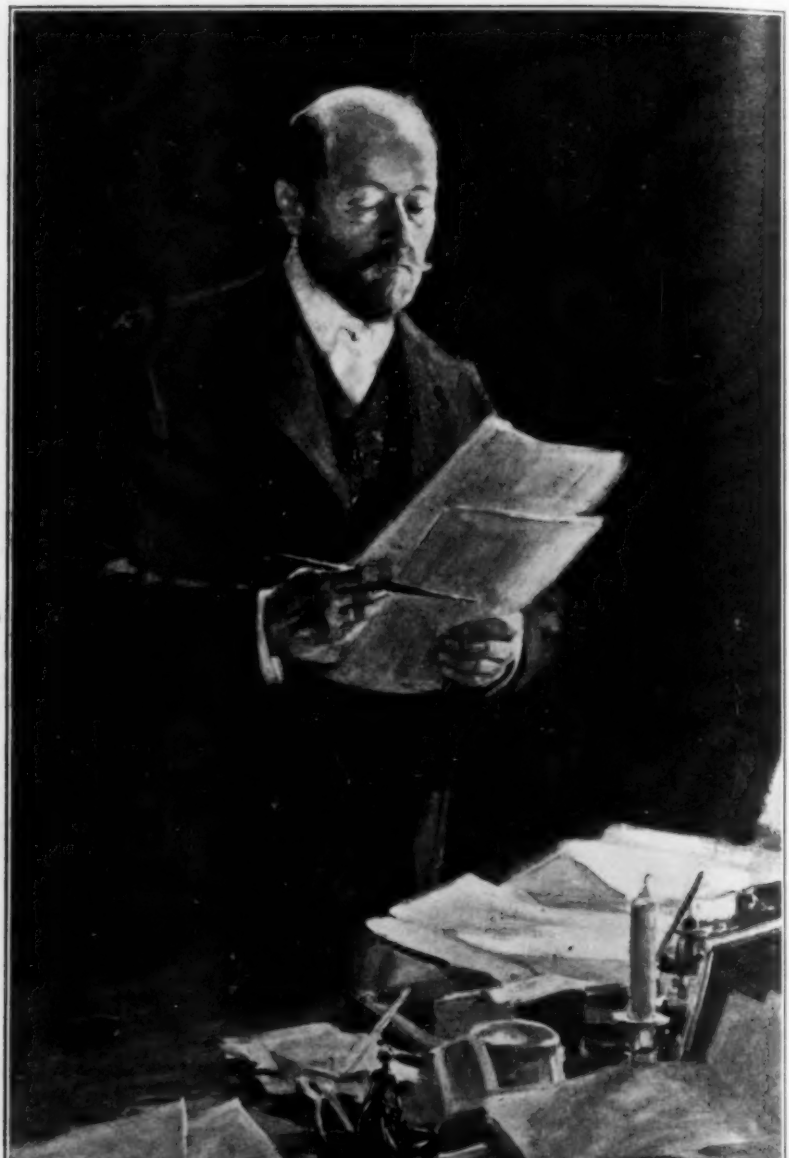
So it seems that we need not depend upon imported sources for our sugar, the tropical cane or the European beet. The Jerusalem artichoke does not come to us from Palestine, but is a native weed, one of our wild sunflowers, that means that it is immune from destructive insects and diseases and needs but little encouragement to make a good crop.

MEASURING ACHIEVEMENT BY ABILITY

SCHOOL teachers are at last beginning to see a way to remedy what has been hitherto regarded as an inevitable defect of the educational process, the appalling waste of the most valuable material in the world, the time, the efforts and the hopes of youth. Year after year as the teacher met the fresh faces in his college classroom he has been saddened by the thought that of these students, perhaps brought there by high ambition, perhaps sent there at parental sacrifice, a certain proportion must fail despite what all that they or he could do. They had all passed the entrance examination and possessed the minimum requirement of knowledge, yet neither he nor they could tell whether they were qualified for the tasks that would be imposed upon them in the next four years, or whether both would lose their labor.

Now, however, it is possible for a high-school senior to find out with a very high degree of probability what will be his success in college studies. The new examinations devised for this purpose are objective, comprehensive, fair and impersonal, and they test both the factors of success, training and aptitude. In one state over 1,500 students have now been followed through their third year at college, and their achievements, in most cases, come close to the predictions based upon these qualifying examinations.

Professor Carl E. Seashore, of the University of Iowa, in his address recently before the National Academy of Sciences on the discovery and motivation of the gifted student, called attention to the amazing magnitude and fixity of individual differences as disclosed by mental measurements. For example, one student may have ten or twenty times as good a memory for the shapes of things as another student has. Or the same person may have ten or twenty times as good memory for such geometrical forms as he



DR. EMIL ADOLF VON BEHRING

The distinguished German immunologist, discoverer of diphtheria antitoxin.

—From a painting by Klein-Chevalier

has for differences in the quality of musical tones. The accurate knowledge of such different aptitudes is of inestimable value in determining whether a boy or girl should undertake training to be an artist or a musician. Such knowledge can be obtained at a surprisingly early age and it is surprisingly persistent. As Professor Seashore says:

"The sense of pitch and the sense of rhythm, for example, may be measured early in childhood and are found to remain constant throughout life except for deterioration, normal or pathological, despite most elaborate education and special training. A boy who is quick and accurate is likely to be the man who is quick and accurate in any particular type of motor process. As our measures of intelligence are gradually improved, we find more and more evidence that the intelligence quotient of 75, 100 or 125 tends to remain fairly fixed throughout life, with or without extensive education of the individual."

On account of the infinite variety of individuals and the wide range of their capacity, it is manifestly unfair to require of them all the same amount of work or the same grades. It has been found that for an examination, which the upper quarter of the class should pass with a grade of 75 per cent., the passing grade of the poorest members of the class, if they made equal effort, should be set at 25 per cent. To set the same requirement for such unequal abilities in the classroom is as unfair to both extremes as it would be in the gymnasium to require them all to jump over a three-foot bar, which for some would be impossible and for others child's play. The new educational slogan, according to Professor Seashore, is "to keep each of the students busy at his highest natural level of successful achievement."

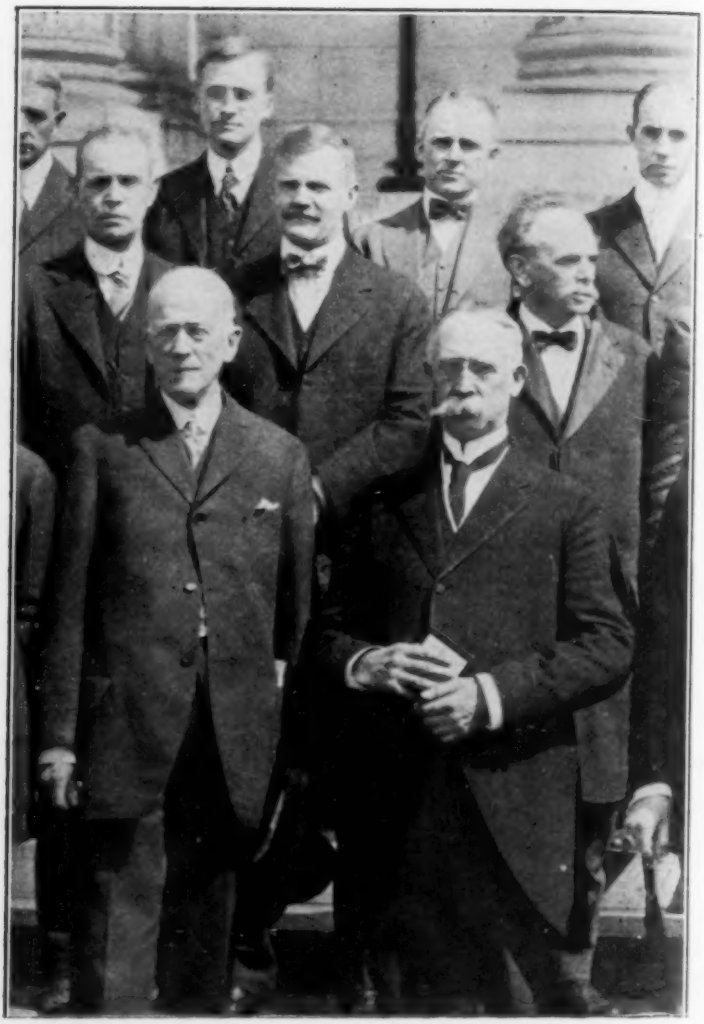
The present practice of whittling down square pegs to fit into round holes may in time be abolished by means of placement tests and vocational guidance. It is coming to be realized that all young Americans are entitled not only to the opportunity for education, but to the particular kind of education to which they individually are fitted for. The old Socialist motto, "From each according to his ability; to each according to his needs," is the motto of the new education.

THE QUESTION OF ETHER DRIFT

A DRAMATIC culmination of a controversy that has divided the scientific world for more than forty years was the appearance upon the same program of the National Academy of Sciences annual meeting of two papers which present new evidence on the question of Einstein's theory of relativity. The first paper was by the president of the academy, Professor A. A. Michelson, of the University of Chicago, whose historic experiments in 1881 first showed that there was something wrong about our traditional ideas of space and time, and so led to the Einstein theory. The second was by Professor Dayton C. Miller, of the Case School of Applied Science, Cleveland, who has recently repeated the original Michelson experiments on the top of Mount Wilson, California, and got different results which conflict with the Einstein theory.

The question at issue is whether there is an ether pervading all space and if so whether it is stationary or is carried along by moving matter.

All attempts to prove the existence of the ether or to measure "ether drift" through moving bodies have so far failed. The crucial experiment



MEMBERS OF THE NATIONAL ACADEMY OF SCIENCES

From a group taken on the steps of the U. S. National Museum, shortly before the death of Dr. Arthur G. Webster, professor of physics in Clark University, who is shown in the foreground on the right. On the left is Dr. Charles D. Walcott, secretary of the Smithsonian Institution, who was in April elected president of the American Philosophical Society, having already been president of the National Academy of Sciences and of the American Association for the Advancement of Science. Above are Dr. Robert G. Aitken, director of the Lick Observatory at Mount Hamilton, California; Dr. Francis G. Benedict, director of the Nutrition Laboratory of the Carnegie Institution at Boston; Dr. Robert A. Millikan, director of the Norman Bridge Laboratory of the California Institute of Technology; Dr. Franz Boas, professor of anthropology at Columbia University, and Dr. Frank B. Jewett, of the New York Telephone and Telegraph Company.

was that tried by Michelson in cooperation with Morley in 1881. He set up in the basement of the Case School a marvelous accurate instrument named the "interferometer," because it measures the interference of fringes, or black and white bands, produced when two beams of light come together in such a way that their crests and troughs conflict.

Besides rotating on its axis from west to east at the rate of a third of a mile a second, the earth revolves around the sun once a year, at a rate of 18 miles a second, and the sun with the earth and the rest of the planets is moving through space at the rate of about 10 miles a second. But whichever way Michelson turned the arms of his interferometer, he found no difference in direction and got no evidence of ether drift. He repeated the experiment in 1887 with more accurate apparatus and in the same place but still got negative results.

This seemed to prove that the earth did not move through a fixed ether. But to assume the contrary, that the earth did not move but was permanently at rest in a fixed ether, was inadmissible because that would upset Copernicus and all the astronomers since.

No adequate explanation of these two conflicting experiments was produced till 1905, when Einstein put forward his special theory of relativity which disregards the ether altogether. This theory carried with it such revolutionary consequences as to the nature of space and time that men began to question whether there might not be some flaw in the Michelson-Morley experiment, on which such a vast edifice of speculation had been built by Einstein and his disciples. So Professor Miller constructed a more elaborate interferometer apparatus with all possible precautions and refinements. When he tried it out in the place of the previous experiments, the basement of the building, he got the same result, that is, no adequate evidence of ether drift.

But a few months ago he set up the apparatus on the summit of Mount Wilson, 5,000 feet above the sea, and this time got a positive displacement of the fringes. If Miller's experiment is confirmed, it would indicate that the ether is somehow tangled up and carried with the earth at points beneath the surface, like the basement laboratory, but that out on a mountain top, somewhat away from the main mass of the earth, the ether does drift by, or through, matter to some extent. This means that we have in the ether a sort of fixed framework and can, in spite of Einstein, get evidence of real motion and not merely relative motion of the stars and the earth. There is then a definite clash between the results so far obtained by Miller and Einstein's special relativity theory.

But the paper read before the academy by Professor H. G. Gale, of the University of Chicago, giving the result of the new experiments by Professor Michelson and himself on ether drift accords with Einstein's theory instead of contradicting it. In this apparatus a divided ray of light was sent in opposite directions through a rectangular water-pipe over a mile long in order to see if the rotation of the earth made any difference on the speed of light in different directions. The measurements with the interferometer were almost exactly the figure required by the theory of relativity, and Professor Michelson in a preliminary announcement of the result in a recent public lecture in Chicago said: "Provisionally there is no question that the Einstein theory is correct and this experiment is one more striking confirmation of his brilliant work." But this result is also in accordance with the old ether theory so it does not definitely decide

THE MACMILLAN ARCTIC EXPEDITION

The map shows the course of the *Bowdoin* from Wiscasset, Maine, to Etah, and back to Nachbak Bay, Labrador. At Etah, the nearest inhabited spot to the North Pole, will be the headquarters of radio station WNP, through which Mr. Macmillan will send home news of the explorations through the National Geographic Society. An airplane base will be established at Cape Hubbard, whence the planes of the United States Navy will fly over the large unknown territory between Cape Hubbard and the North Pole, at both of which the flag of the United States has been raised. Airplanes will also undertake to make a reconnaissance of North Greenland, concerning the inland ice of which comparatively little is known. Nansen, in 1888, crossed Greenland directly from east to west. That cross-section was made, however, below the Arctic Circle where the island-continent is about three hundred miles across. Peary cut across the northwest corner in the nineties. The only other crossings were those of Rasmussen and De Quervain, each in 1912, and Koch, in 1913. The airplanes will also explore Ellsmere Island and Baffin Island and, on their return, parts of Labrador. Of particular interest, however, will be the exploration of the vast unknown region between Fort Barrow, Alaska, and the North Pole.

between them. Besides, this experiment was performed underground like those in the basement of the Case School and, if Professor Miller's experiments are right, different results may be expected on the mountain tops.

With the possible exception of Miller's recent results on Mount Wilson, the Einstein theory has been substantiated on all points open to experimental evidence. His prediction of a displacement in the position of stars close to the sun was verified by eclipse observations of Eddington, of England, and Campbell, of California. His prediction of a shift in the spectral lines from the sun was verified by St. John at Mount Wilson. The theory of relativity also affords an explanation of the irregularities in the orbit of Mercury, the distribution of the fine lines of the spectrum of light as calculated by Sommerfeld, of the results of the Michelson-Morley experiment and of the continued production of heat from the sun and stars by the conversion of their substance into radiant energy.

METHANOL

THE public should get acquainted with methanol, which they have hitherto known, if at all, by the name of "wood alcohol" or "methyl alcohol." Its new name—accent on the first syllable, please—will tend to prevent the frequent and sometimes fatal confusion of methyl with her sister ethyl, who is the more sought after and less deadly member of the family. Many a man has asked the druggist for "alcohol" for horse-liniment or cleaning his typewriter, and the druggist, not noticing the wink, has given him the kind of alcohol that makes a man drunk blind instead of blind drunk. Alcohol for industrial purposes is often denatured with methanol and when it is de-denatured for beverage purposes some of this is likely to be left in. Because of such accidents conscientious bootleggers are said to furnish free with each case of their whiskey a bundle of pencils and a card, "I am blind," so that the purchaser is insured of a livelihood in case of the worst.

Methanol in its proper place, which is outside the human stomach, is a useful article in many manufactures and some eight million gallons have been made in America annually by the distillation of wood. But this method of manufacture is now hard hit by a new process which uses coal and water as the raw material. The first step in the process is the formation of the well-known "water-gas" by passing steam over hot coal. This gas is a mixture of carbon monoxide and hydrogen, both good combustibles. When the water-gas, mixed with more hydrogen, is subjected to heat and pressure in the presence of a catalyst the carbon monoxide and the hydrogen combine to form methanol.

This synthesis is similar to the Haber process which combines the nitrogen from air with hydrogen from water gas to form ammonia. By means of the Haber process Germany has been supplied with fixed nitrogen for explosives in war time and fertilizers in pence time.

The new process may prove to be equally important since by slight variations the same raw materials may be made to yield acetone, a useful solvent, formaldehyde, a familiar disinfectant, and an oily mixture, resembling petroleum, from which gasoline may be made. The demand for formaldehyde has greatly grown of late because it is one of the two ingredients of synthetic resins, such as bakelite, which give us music by means of radio receivers and phonograph records. Methanol is being increasingly employed as a solvent in lacquers and the like, and is used in making many dyes and drugs.

The inventor of the methanol process, Dr. Franz Fischer, director of the Kaiser-Wilhelm Institute at Mulheim-Ruhr, is now in this country and gave a talk at the recent Baltimore meeting of the American Chemical Society. In his process he puts the mixture of hydrogen and carbon monoxide under a pressure of 1,050 pounds per square inch at a temperature of 410 degrees Centigrade. The catalyst, that is, the agent that effects the combination of the gases, is zinc oxide. The Badische plant at Merseburg turns out twenty tons of methanol a day.

The basic Badische patent on this process was granted on October 17, 1916, in the United States. When we entered the war this was taken over with the other German patents by the Alien Property Custodian and transferred to the Chemical Foundation, which grants non-exclusive licenses to American manufactures. Later developments of the process have been patented in Germany and France in 1923. The French experiments have been carried out by M. Patart with the aid of the Ministry of Commerce and Ministry of War, and are described in *Industrial and Engineering Chemistry* of April, 1925. It is estimated that synthetic methanol may be made by this method at about twenty cents a gallon, which is less than a third of the present American price for the product of wood distillation.

CORRESPONDENCE

THE GOVERNOR OF CALIFORNIA AND THE REGENTS OF THE STATE UNIVERSITY

To the Editor of The Scientific Monthly:

The Scientific Monthly for April, 1925, page 417, publishes the following from the anonymous pen of "The Research Worker, Stanford University":

"Look at the governor of California refusing to endorse modern hygienic measures for fear of alienating the Christian Science vote. The regents of our state university (of California) denying adequate appropriation to the medical department for fear of antagonizing the Protestant religio-therapeutic bloc."

I have no right to speak for the governor of California, but undoubtedly my relations with him are more intimate than are those of "The Research Worker." In my opinion, California has a courageous governor, who acts in accordance with his own conscience, and without reference to capturing or to alienating the votes of any group.

As a result of my intimate relationships with "the regents of our state university," in the past two years, I have encountered no fact, or even the remotest suggestion of a fact, which "The Research Worker" could make the basis for saying that the regents are paying any attention to any "bloc" of voters, religio-therapeutic or otherwise. I am convinced that a little bit of "research" would have saved "The Research Worker, Stanford University" from assuming the unenviable position of publishing anonymously a libellous statement concerning the governing board of another university.

W. W. Campbell,
President of the University of California

Berkeley, California,
April 29, 1925

[No journal is responsible for the opinions expressed in the articles that it publishes. The editor of this particular journal, being a psychologist by profession, would hesitate to ascribe motives for any action, whether it be of a governor of a state or of a research worker, except as a working hypothesis formed from the total behavior of an individual. This, however, is not the usual procedure, and men are hung or elected president of the nation on the supposition that we know the motives that have led to their actions. In a democracy it is desirable to allow free expression of opinion concerning those elected to public office.—EDITOR.]

CHRISTIAN SCIENCE

TO THE EDITOR OF THE SCIENTIFIC MONTHLY:

It is regrettable to find a publication such as THE SCIENTIFIC MONTHLY lending itself to a malicious attack upon the religious teachings and healing ministry of Christian Science. This I may add is especially true in respect to an offensive article appearing in your April issue where the writer hides his identity behind a *nom de plume* but openly trades upon the good name of a well-known university. This person, whoever he may be, writes as one completely blinded by a bitter prejudice and what is more, he proceeds with a flagrant disregard of demonstrated results to malign a great religious organization and cast reflections upon the integrity of the multiplied thousands who go to make up its adherents. It is one thing to disagree with the teachings of Christian Science; but quite another to deliberately accuse Christian Scientists of falsity and misrepresentation. I, of course, recognize it as the privilege of your contributor to express his opinion regarding Christian Science, but I must deny his right to misrepresent the purposes of the Christian Science Church and publicly impugn the motives of its members.

His statement, for instance, that published testimonies of Christian Science healing were untrue and that the efficacy of Christian Science treatment had been adversely reported upon after an impartial investigation is wholly without warrant. Numerous committees have been appointed by religious and medical organizations to investigate so-called faith healing and the various modes of suggestive therapy, all of which are, however, the very antithesis of Christian Science teaching and practice. For your information I may say that the Christian Science Church uses the greatest measure of care in investigating testimonials of healing before they are published in the authorized periodicals of the movement. Such testimonies are certified to by at least three responsible persons.

I may also add that practically every known form of disease, including those diagnosed by responsible medical practitioners, has been successfully treated in Christian Science. I have on file in my office testimonies from dependable citizens of this state gratefully acknowledging the healing of disease diagnosed as organic by reputable physicians and in many instances pronounced incurable. Interesting enough, at or about the time our critic's article came to my desk a much respected lady of this city delivered to me a written testimony of her healing of cancer through Christian Science treatment. The lady's brother, a prominent business man also of this city, joined his sister in certifying to the healing. Such practical demonstrations have served to make a profound impression upon a substantial wing of the medical profession itself. As an example, Dr. Richard C. Cabot, of Harvard University, one of America's best known and most highly re-

spected medical authorities, has said, "We are firmly convinced that Christian Science has done and is doing a vast deal of good not only as a religion but as a health restorer and a protest against the short-sighted naturalness of the doctors." Equally interesting is the following statement from Lt.-Col. Frank T. Woodbury, M.D., of Edgewood Arsenal, "Every day we hear people remark that they had been given up by several physicians and finally went to a practitioner not of the regular medical school and were cured. I formerly thought that it was a case of exaggeration or of self-delusion, but I feel that we can not dismiss these testimonies with a learned bromide. The results of irregular practice are all around us. Ten Christian Science Churches in New York City alone [there are actually thirty-one] can not be blown away with a laugh. We have to admit that these sects and cults possess a knowledge of healing which we do not recognize." If space permitted almost countless citations such as the foregoing could be offered as evidence that a substantial number of physicians who occupy ranking positions in their profession wholly disagree with our critic's attitude towards Christian Science.

In view of the seriousness of your contributor's misrepresentations I respectfully request that you publish this correction without delay.

Sincerely yours,

CHARLES E. HEITMAN,
Christian Science Committee on Publication

NEW YORK, N. Y.,
APRIL 30, 1925

[WE have received a number of letters objecting to the criticism by "The Research Worker" (who is a distinguished man of science) of the medical activities of Christian Science and print one that claims to be official. Dr. Cabot may be correct in holding that "Christian Science has done and is doing a vast deal of good not only as a religion but as a health restorer" in so far as it teaches its adherents to forget minor ills and to be hopeful in regard to the future. But when it is officially claimed by Mr. Heitman that Christian Science cures practically every known form of organic disease, including cancer, then it is no longer a question of the attitude of scientific men on the validity of such claims, but only to what extent the law should be invoked for the protection of the incompetent.—EDITOR.]

INDEX

NAMES OF CONTRIBUTORS ARE PRINTED IN SMALL CAPITALS

ABBOT, C. G., Where are the Stars? 616
ADAMS, C. C., Ecological Conditions in National Forests and Parks, 561
African Manlike Ape Skull, 334
American Association for the Advancement of Science, group of members, Photograph, 218
Anarchy in the Human Body, 106
Anesthesia, Surgical, C. D. LEAKE, 304
ANTEVS, E., Glacial Conditions, 464
ASTON, F. W., Atoms and Isotopes, 128

BALL, M. V., Conservation of Vision, 278
Baseballs, American, 443
Beal, William James, Photograph, 552
BEARD, J. H., Medical Observations of Lewis and Clark, 506
Behring, Emil Adolf von, Photograph, 662
BELKIN, M. and W. CRAIG, Rickets, 541
Biology, Systematic, C. F. FERRIS, 657
Botanizing, in Peru, A. S. HITCHCOCK, 47; in Bolivia, A. S. HITCHCOCK, 163
BOWEN, E., Progress, 159
BRAGG, W., X-Rays and Crystal Structure, 115
Brandeis, Louis D., Photograph, 102

CAJORI, F., The Baconian Method of Scientific Research, 85
CAMPBELL, W. W., Governor of California and Regents of the University, 668
Cave Dwellers, R. WILLIAMS, 40
Chromosomes, Endocrines and Heredity, C. B. DAVENPORT, 491
Civilization, Western, H. S. GRAVES, 225; W. A. REID, 235; B. M. LUCKEY, 245; J. E. GREGG, 248; R. H. JOHNSON, 254; J. MAYER, 257; H. C. METCALF, 269; M. V. BALL, 278; R. H. HALSEY, 282
CLARK, A. H., Animal Flight, 5; Animal Coloration, 341
Classicism, The Revival of, and the Legend of Socrates, J. WRIGHT, 369
Climates, Ancient, W. J. HUMPHREYS, 449; T. W. STANTON, 459; E. ANTEVS, 464; D. WHITE, 465; A. P. COLEMAN, 473; S. S. VISHER, 475
COBLENTZ, W. W., Life on Mars, 337
COCKERELL, T. D. A., Japan in 1923, 405
COLEMAN, A. P., The Ice-Ages, 473
Coloration, Animal, A. H. CLARK, 341
Cooperation among Scientific Men, W. P. TAYLOR, 345
CRAIG, W., and M. BELKIN, Rickets, 541

DANFORTH, R. E., Religion and Human Evolution, 183
DAVENPORT, C. B., Chromosomes, Endocrines and Heredity, 491
Disease, The Physical Basis of, THE RESEARCH WORKER, 64, 176, 297, 416, 499, 647; Seasonal Prevalence of, M. J. ROSENAU, 192; New, 331
DYSON, F., Relativity, 288

Eclipse, Total, of Jan. 24, 1925, 110
EELLS, W. C., Center of Population, 78
Einthoven, Willem, Photograph, 104
Electrifying the Skin, 557
Epidemiology, I. S. FALK, 383
Ether Drift, 663
Ethics, the Geometry of, 105

FALK, I. S., Epidemiology, 383
Feeding in Childhood, C. H. RICE, JR., 379
FERRIS, G. F., Systematic Biology, 657
FLEMING, J. A., Thermionic Valves, 530
Flight, Animal, A. H. CLARK, 5
Forests and Parks, National, Ecological Conditions in, C. C. ADAMS, 561
FOWLER, A., Origin of Spectra, 534

Gasoline, Artificial, 329
Geographers, Photograph, 220
Germ-killer, Hunt for, 553
GLAZEBROOK, R., Wireless, 291
GOLD, E., Weather Forecasting, 629; Gold, Artificial, 445
Grasshoppers, Mountains of, 447
GRAVES, H. S., Conservation Problem of Paper and Pulp Industry, 225
Gravitation, W. D. LAMBERT, 479
GREGG, J. E., Comparison of Races, 248

HALSEY, R. H., Heart Disease, 282
Health Book, Old, J. F. ROGERS, 73
HEITMAN, C. E., Christian Science, 669
HESS, F. L., Age of the Earth, 597
HEYL, P. R., Weighing the Earth, 602
Hillebrand, William F., Photograph, 442
HITCHCOCK, A. S., Botanizing in Peru, 47; in Bolivia, 163
HUMPHREYS, W. J., Climatic Control, 449

Inconsistency, G. W. STEWART, 153

International, Cooperation, 217

Japan in 1923, T. D. A. COCKERELL, 405
JEFFERS, D. S. and C. F. KORSTIAN, Trail of the Vanishing Spruce, 358
Jennings, Herbert Spencer, Photograph, 660
JOHNSON, R. H., International Migration, 254

Kelp and Goiter, J. W. TURRENTINE, 27
Kiess, C. C., Photograph, 335
KORSTIAN, C. F., and D. S. JEFFERS, Trail of the Vanishing Spruce, 358

LAMBERT, W. D., Gravitation, 479
LEAKE, C. D., Surgical Anesthesia, 304
Lewis and Clark, Medical Observations and Practice of, J. H. BEARD, 506
LIND, S. C., Radium, 606
LLOYD, A. H., Mathematician Pascal as Philosopher and Saint, 139
Locomotives, New Fashions in, 551
Loeb, Jacques, Photograph, 102
LUCKEY, B. M., Racial Differences, 245

MCLENNAN, J. C., Helium Gas, 424
Macmillan Arctic Expedition, Map, 666
Mars, Life on, W. W. COBLENTZ, 337
MAYER, J., Business Education and Research, 257
Measuring Achievement by Ability, 661
Members of National Academy of Sciences, Photograph, 664
Memory, Testing and Training, 111
MERRITT, E., Scientific Discoveries, 594
METCALF, H. C., Employee Representation, 269

Osterhout, W. J. V., Photograph, 556
Oxford Univ. Arctic Expedition, 332

PAIGE, S., Earthquakes, 611
Pascal, The Mathematician, as Philosopher and Saint, A. H. LLOYD, 139
Pawlow, Ivan Petrovic, Photograph, 330
Phosphorus, The Glow of, LORD RAYLEIGH, 92
Population Center, W. C. EELLS, 78; W. A. REID, 235
President of the U. S., Address, 215
Progress, of Science, E. E. SLOSSON, 103, 215, 329, 443, 551, 659. By Accident or Plan, E. BOWEN, 159.
Pupin, Michael Idvorsky, Photograph, 222

Radio, Photo-letter Machine, 108; Talks on Science, E. MERRITT, 594; F. L. HESS, 597; P. R. HEYL, 602; S. C. LIND, 606; S. PAIGE, 611; C. G. ABBOT, 616
Rare Earths, 103
RAYLEIGH, LORD, The Glow of Phosphorus, 92
Rays, Death-dealing and Labor-saving, 108
REID, W. A., Population of S. A., 235
Religion and Human Evolution, R. E. DANFORTH, 183
RESEARCH WORKER, The Physical Basis of Disease, 64, 176, 297, 416, 499, 647
Research, Scientific, F. CAJORI, 85
RICE, C. H., JR., Feeding Problems of Childhood, 379
Rickets, W. CRAIG and M. BELKIN, 541
ROGERS, J. F., Old Health Book, 73
ROSENAU, M. J., Seasonal Prevalence of Disease, 192
RUTHERFORD, E., Electricity and Matter, 121

Science, State of, in 1924, J. J. THOMSON, 113; W. BRAGG, 115; E. RUTHERFORD, 121; F. W. ASTON, 128; F. DYSON, 288; R. GLAZEBROOK, 291; J. C. MCLENNAN, 424; J. E. SEARS, 427; N. SHAW, 436; J. A. FLEMING, 530; A. FOWLER, 534; E. GOLD, 629; G. C. Simpson, 621
SEARS, J. E., Fine Measurement, 427
SHAW, N., Circulation of the Atmosphere, 436
SHAW, W. T., Columbia Ground Squirrel, 483
SIMPSON, G. C., Water in the Atmosphere, 621
SLOSSON, E. E., Progress of Science, 103, 215, 329, 443, 551, 659
SMYSER, S., Frederick Taylor, 527
Spruce, Vanishing, On the Trail of, D. S. JEFFERS and C. F. KORSTIAN, 358
STANTON, T. W., Climatic Zones, 459
STEWART, G. W., Inconsistency, 153
Sugar from Sunflowers, 659

Taylor, Frederick, S. SMYSER, 527
TAYLOR, W. P., Cooperation among Scientific Men, 345
THOMSON, J. J., The Electron, 113
Tondorf, Francis A., Photograph, 446
TURRENTINE, J. W., Kelp and Goiter, 27

VISHER, S. S., Glacial Period, 475

War Debts, Painless Way of Paying, 555
Washington, Henry S., Photograph, 334
Weight, how to lose, 559
Welch, William H., Photograph, 554
Wherry, Edgar T., Photograph, 444
WHITE, D., Upper Paleozoic Climate, 465
WILLIAMS, S. R., Cave Dwellers, 40
WRIGHT, J., Revival of Classicism and the Legend of Socrates, 369

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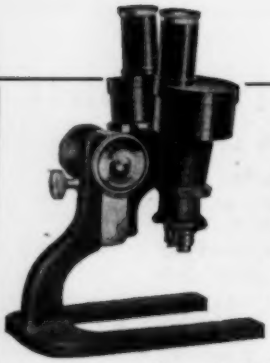

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